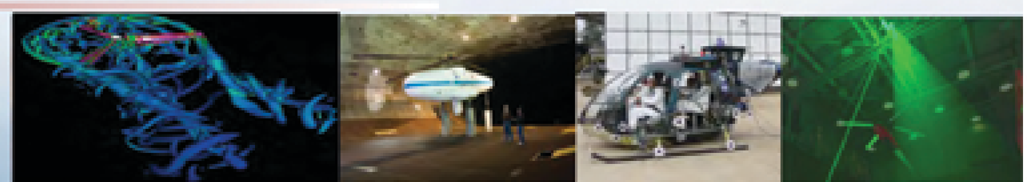
National Aeronautics and Space Administration

Overview of Subsonic Rotary Wing Project



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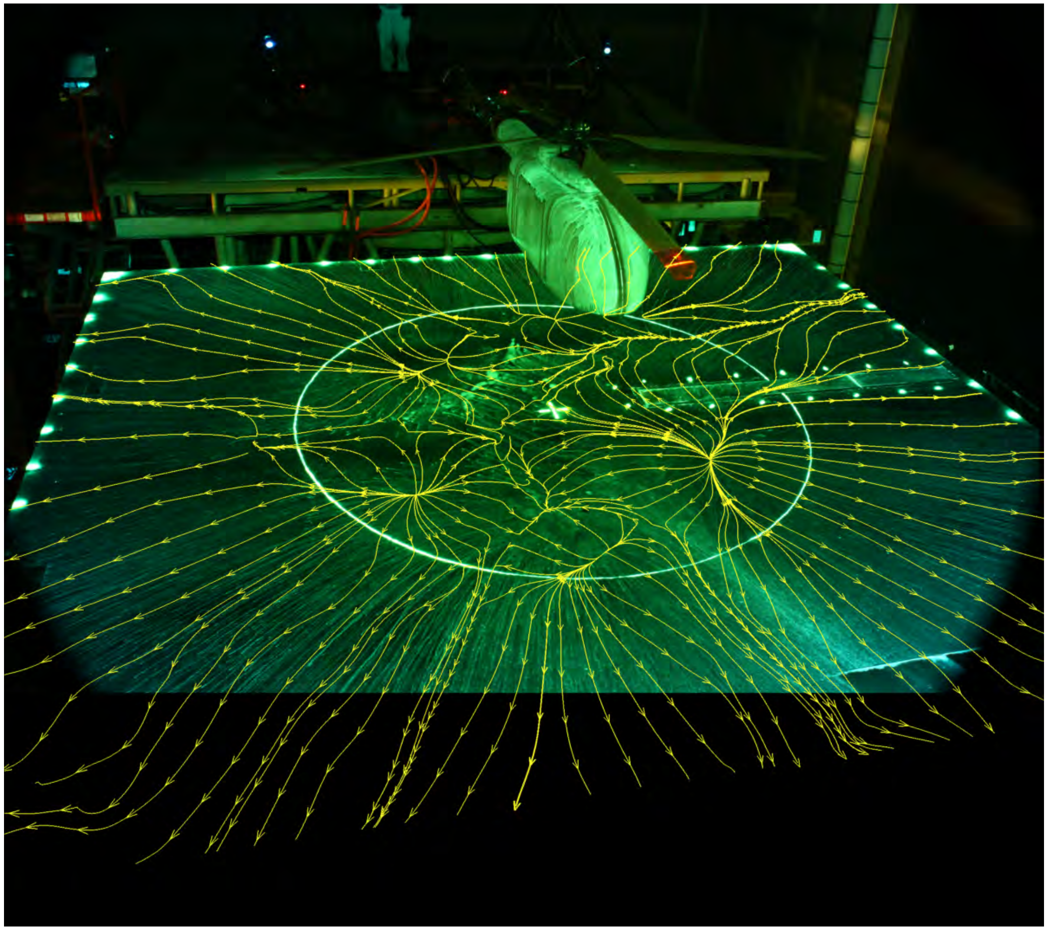
Outline

- NASA Aeronautics Overview
- Rotary Wing Goals
- System Study Results
- Technical Challenges
- Discipline Areas
- Upcoming Activities
- Roadmapping



Rotor in hover ground effect. CFD streamlines superimposed on oil flow visualization

NASA Organization

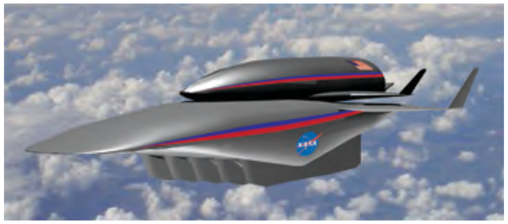
- Office of the Administrator
  - 
    Science Mission Directorate (SMD)
  - 
    Aeronautics Research Mission Directorate (ARMD)
    - Fundamental Aeronautics Program (FAP)
    - Airspace Systems Program (ASP)
    - Integrated Systems Research Program (ISRP)
    - Aviation Safety Program (AvSafe)
    - Aeronautics Test Program (ATP)
  - 
    Exploration Systems Mission Directorate (ESMD)
  - 
    Space Operations Mission Directorate (SOMD)
  - …

National Aeronautics Policy & Plan; NASA Strategic Plan

- **National Aeronautics R&D Policy (Dec 2006) and Plan (Dec 2007, Feb 2010)**
  - “Mobility through the air is vital…”
  - “Aviation is vital to national security and homeland defense”
  - “Assuring energy availability and efficiency is central…” and “The environment must be protected…”
- **NASA Strategic Plan**
  - Strategic Goal 4: “Advance aeronautics research for societal benefit”
- **NextGen: The Next Generation Air Transportation System**
  - Joint Planning Development Office (JPDO), Vision 100 (2003)
  - Revolutionary transformation of the airspace, the vehicles that fly in it, and their operations, safety, and environmental impact

Fundamental Aeronautics Program

Goal: Develop capabilities necessary to address national challenges in air transportation including noise, emissions, fuel consumption, acceptable supersonic flight over land, mobility, and the ability to ascend/descend through atmospheres.



Subsonic Rotary Wing (SRW)

Radically improve the transportation system using rotary wing vehicles by increasing speed, range, and payload while decreasing noise, vibration and emissions.

Subsonic Fixed Wing (SFW)

Develop improved prediction methods and technologies that enable dramatic improvements in noise and emissions reduction, and increased performance characteristics of subsonic/transonic aircraft.

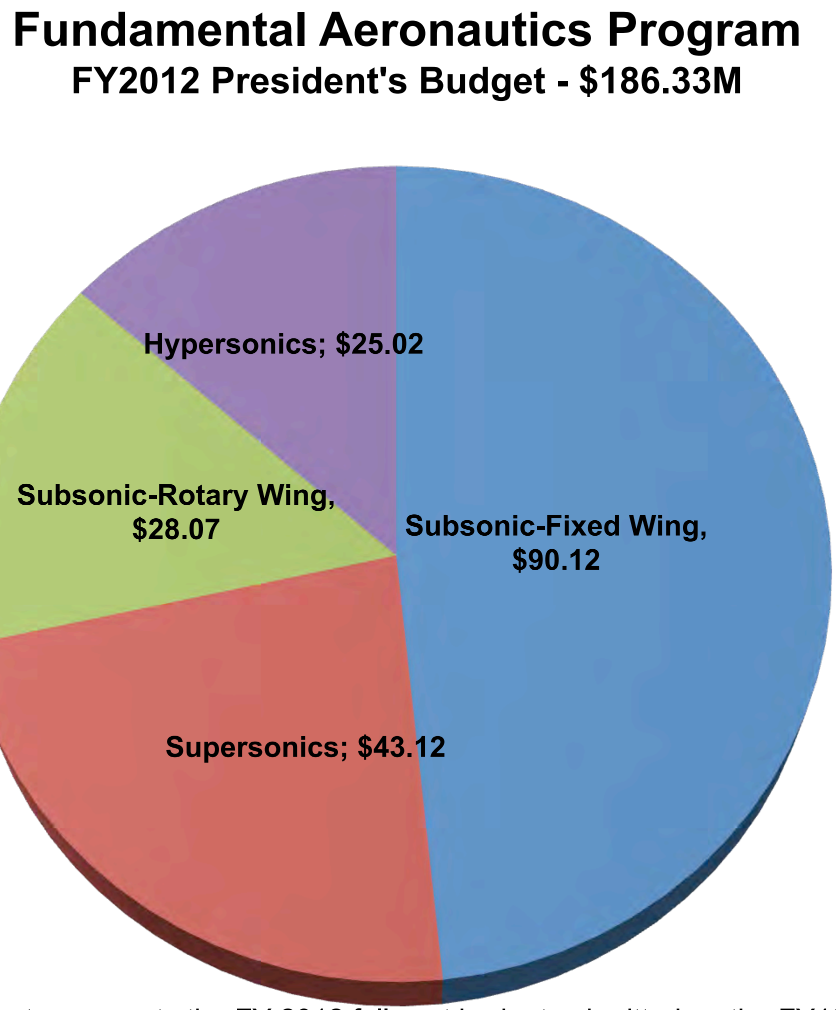
Supersonics

Eliminate environmental and performance barriers to practical supersonic transportation (sonic boom and airport noise, emissions, cruise efficiency).

Hypersonics

Enable airbreathing access to space and high mass entry into atmospheres.

FY2012 President’s Budget



Note: The budget represents the FY 2012 full cost budget submitted on the FY12 President’s Budget

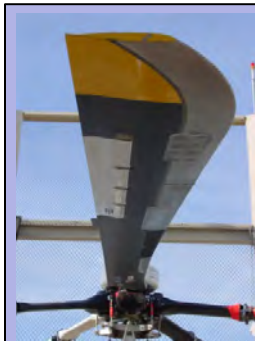
NASA's View of the Research World

- Industry (produces vehicles)
  - 1-5 year fleet insertion
  - Customer driven
  - Manufacturing technology
  - Reliability
  - Maintenance
- DOD research laboratories (DOD buys, owns, operates vehicles)
  - 5-15 year fleet insertion
  - Mission and capability/needs driven
  - Affordability
- NASA rotary wing research (does not make, buy, own or operate vehicles)
  - 10-35 year fleet insertion
  - Vision driven with commercial focus
  - Research to define technology boundaries
  - Pathfinding
  - Multi-mission, multi-customer
  - No direct research in the "—ilities"

Challenges for Future Rotorcraft

NextGen Integration

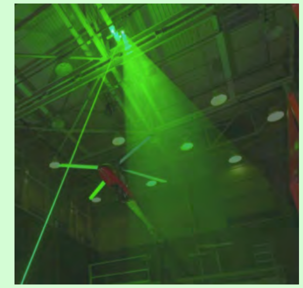
Advanced rotorcraft in the NextGen airspace require integration and commercial operation considerations

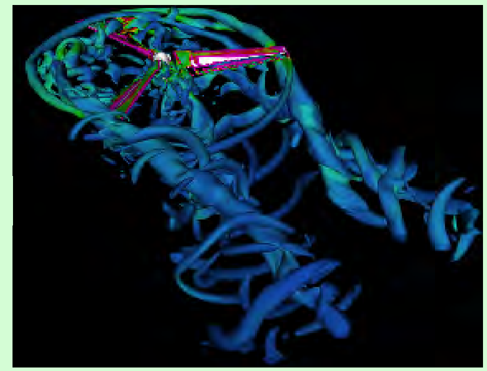


Active rotor systems
High-speed configurations for efficient transport systems require advanced aerodynamic performance: high-lift, low drag, low vibration, low noise rotors.

Modeling and Validation

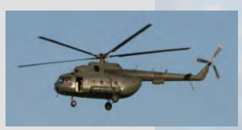
Physics-based Multi-disciplinary design and analysis tools required to design new configurations. New computational and measurement systems required to understand rotor wake system.

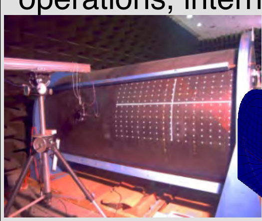


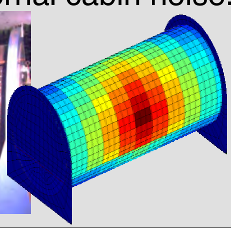


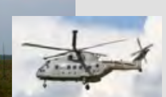
Low Noise: External and Internal

Address barrier technologies in external source noise, low noise operations, internal cabin noise.

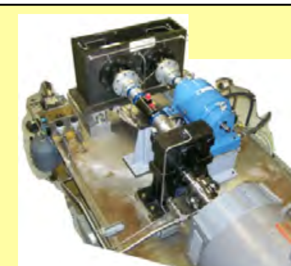


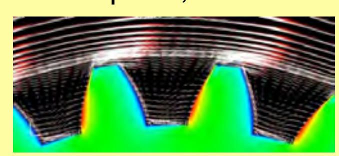


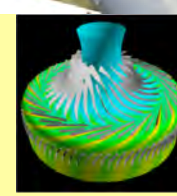




Propulsion System
Engine improvements needed in technology and efficiency.
Drive Train and transmission advanced design required for variable speed, low noise, high efficiency



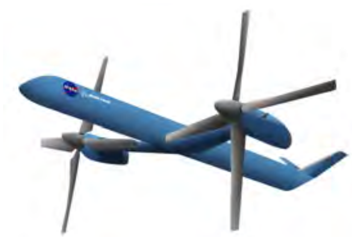




Recent System Studies

- Large Civil Tiltrotor, 2nd Generation (LCTR2) (2008, in-house)
- Technology Benefit Assessment for Compound and Tiltrotor Systems (contract, completed Dec 2008)

- Future Concepts in the NextGen (completed, Dec 2009)
- Tiltrotor Fleet Operations in the NextGen (completed year 2 of 3 year contract)
- Propulsion-Airframe integration study (on-going, under contract)

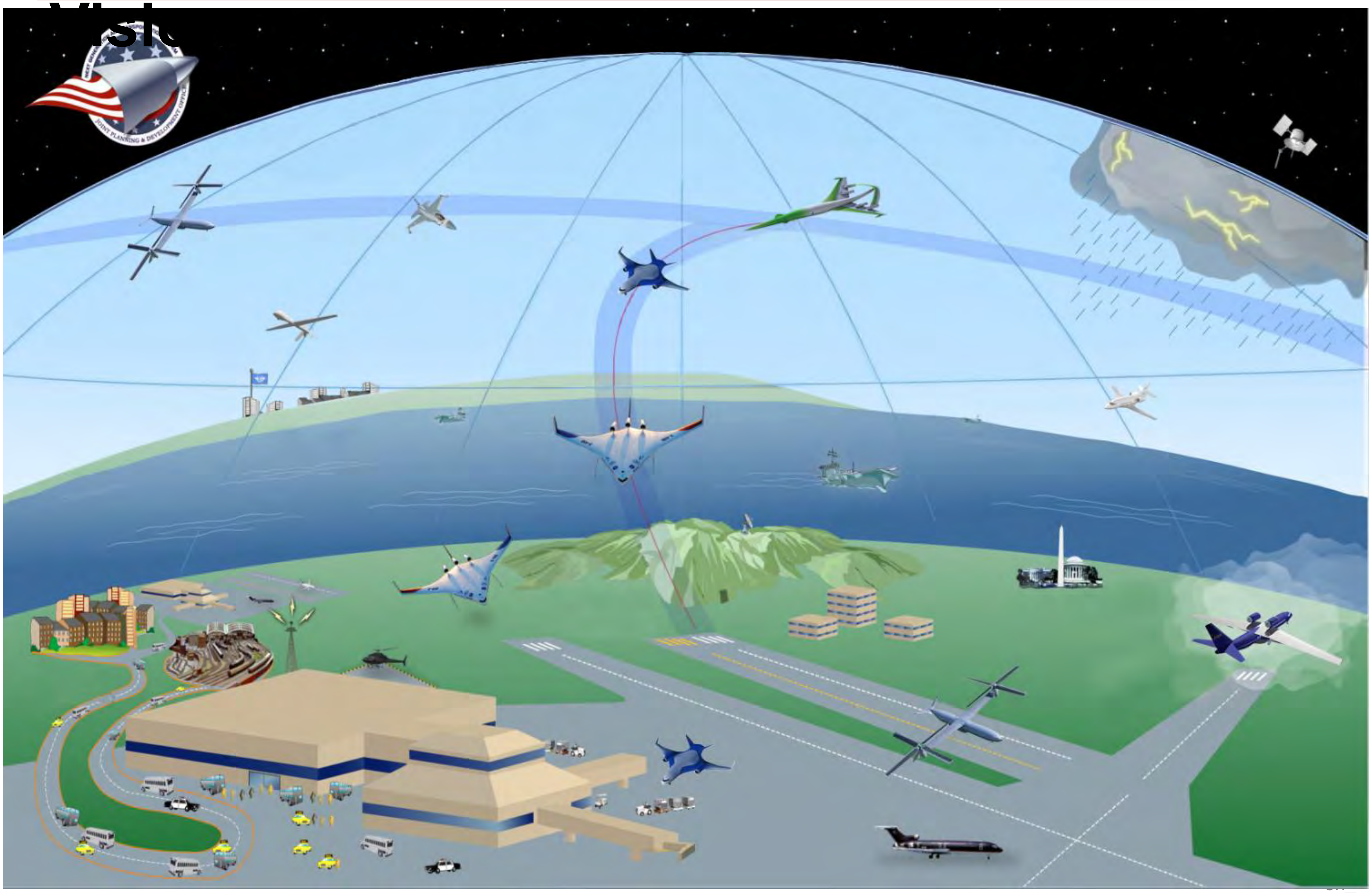


Why large transport rotorcraft configurations?

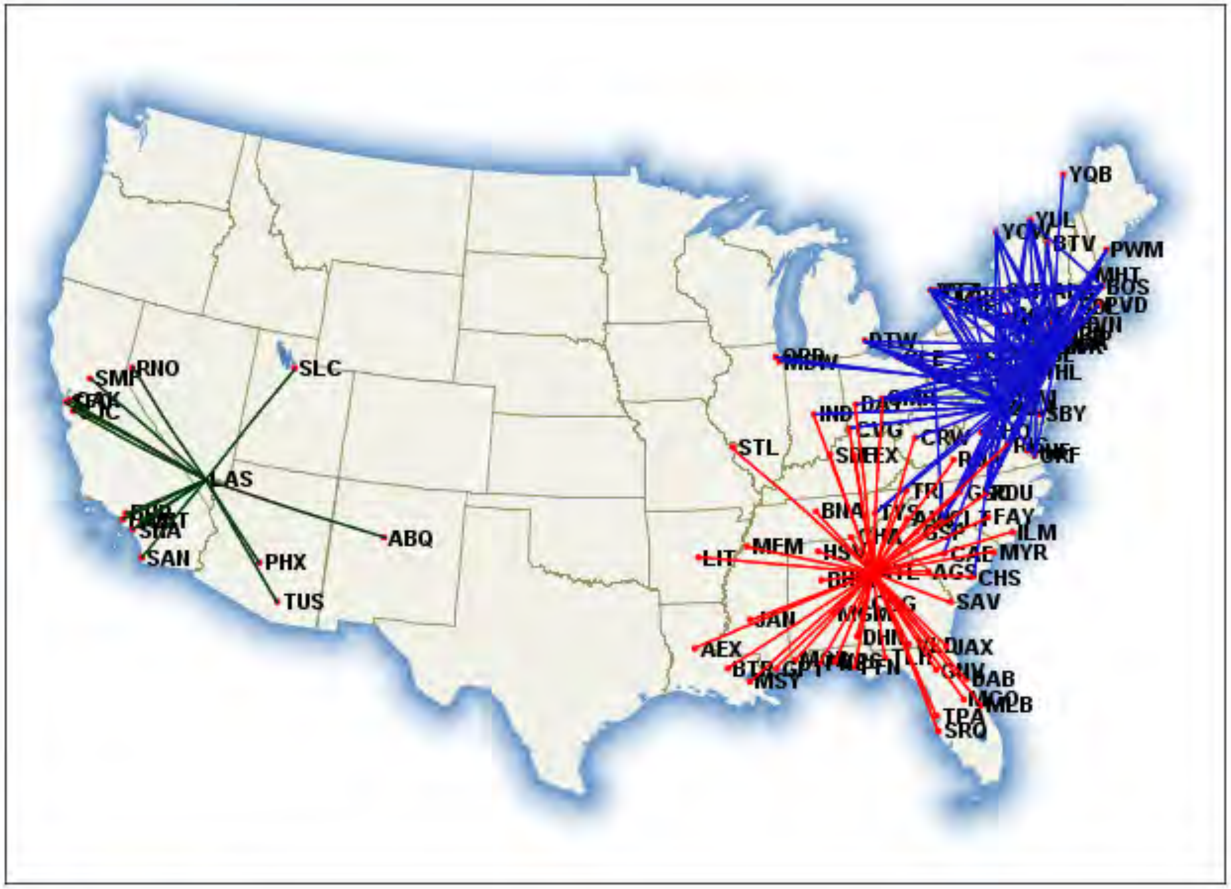
- NASA Aeronautics directed to support NextGen technologies and capabilities
- Congestion/capacity an issue in NextGen
- Vertical capability at one or both ends of a mission increases capacity, particularly in the 300-600nm flight range
- Simultaneous, Non-Interfering (SNI) approaches need to be evaluated in the current NextGen CONOPS

System studies to date have consistently shown these types of configurations will improve capacity and mobility.

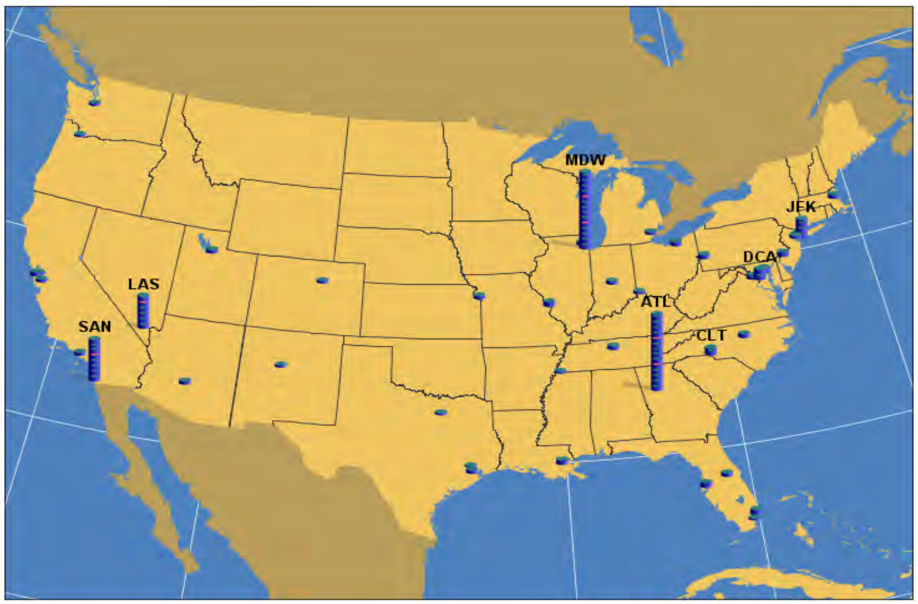
Rotorcraft are Part of the NextGen Visi



CTR30, 90 & 120 Mixed Regional Networks



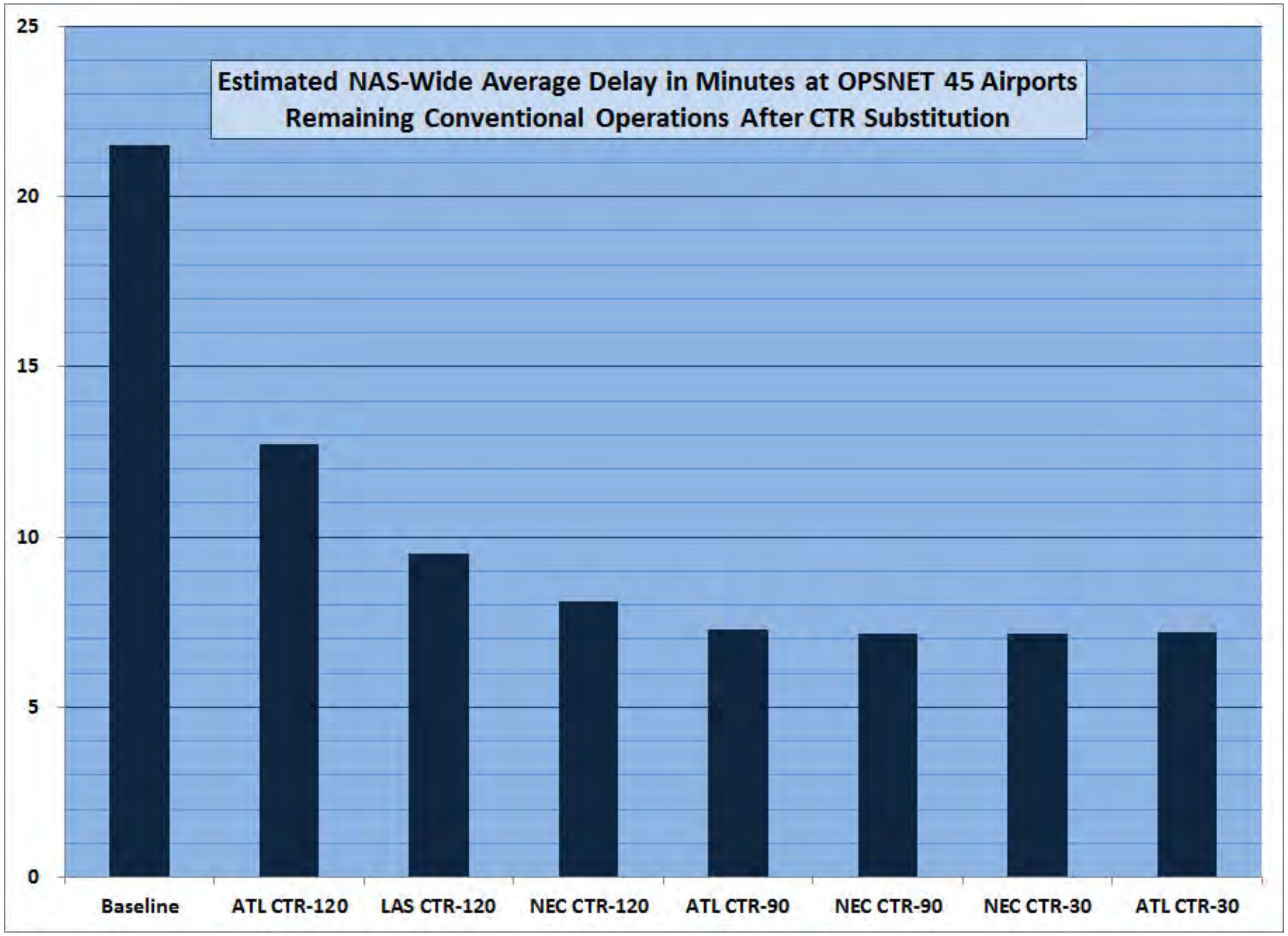
Delays for a Mixed Fleet of CTR 30, 90, 120



Baseline Delays

Test Point 3.4

Average Delay Reduction (NAS-wide) from CTR Substitution

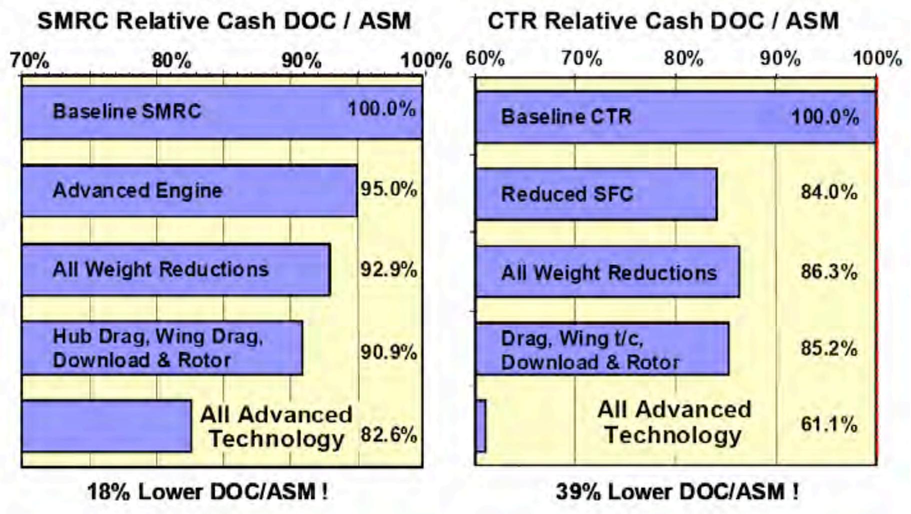


Technology Benefit Assessment Study

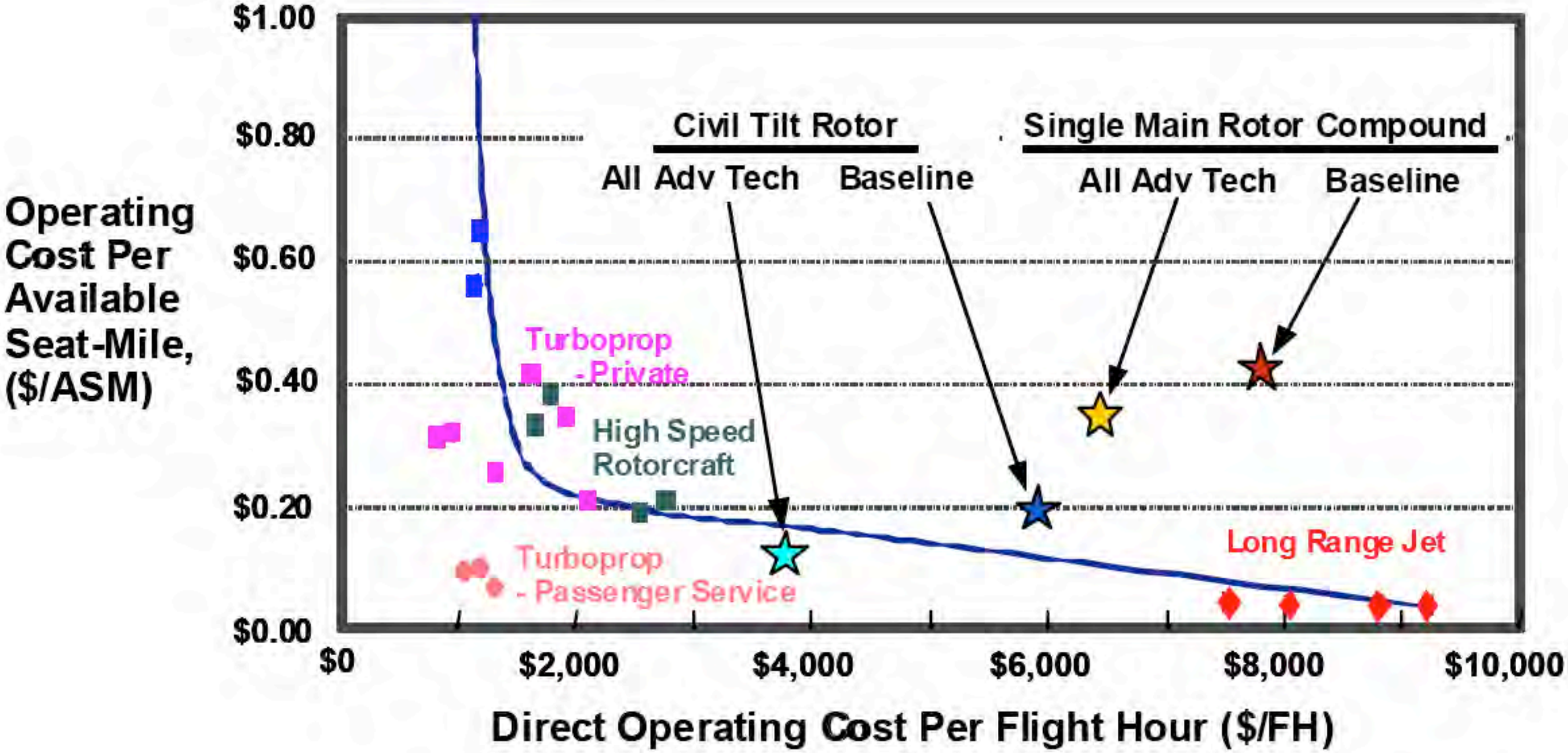
Study Objective: assess technologies that have significant benefit for Single Main Rotor Compound (SMRC) and Civil Tiltrotor (CTR) configurations

- Conducted by Boeing under NASA contract
  - Results published: NASA Contractor Report 2009-214594
  - Metric: Direct Operating Cost per Available Seat Mile (DOC/ASM)

- Results: most beneficial technologies for mission
  - Engine fuel flow
  - Structural weight
  - Drive system weight
  - Parasite drag
  - Rotor hover and cruise performance

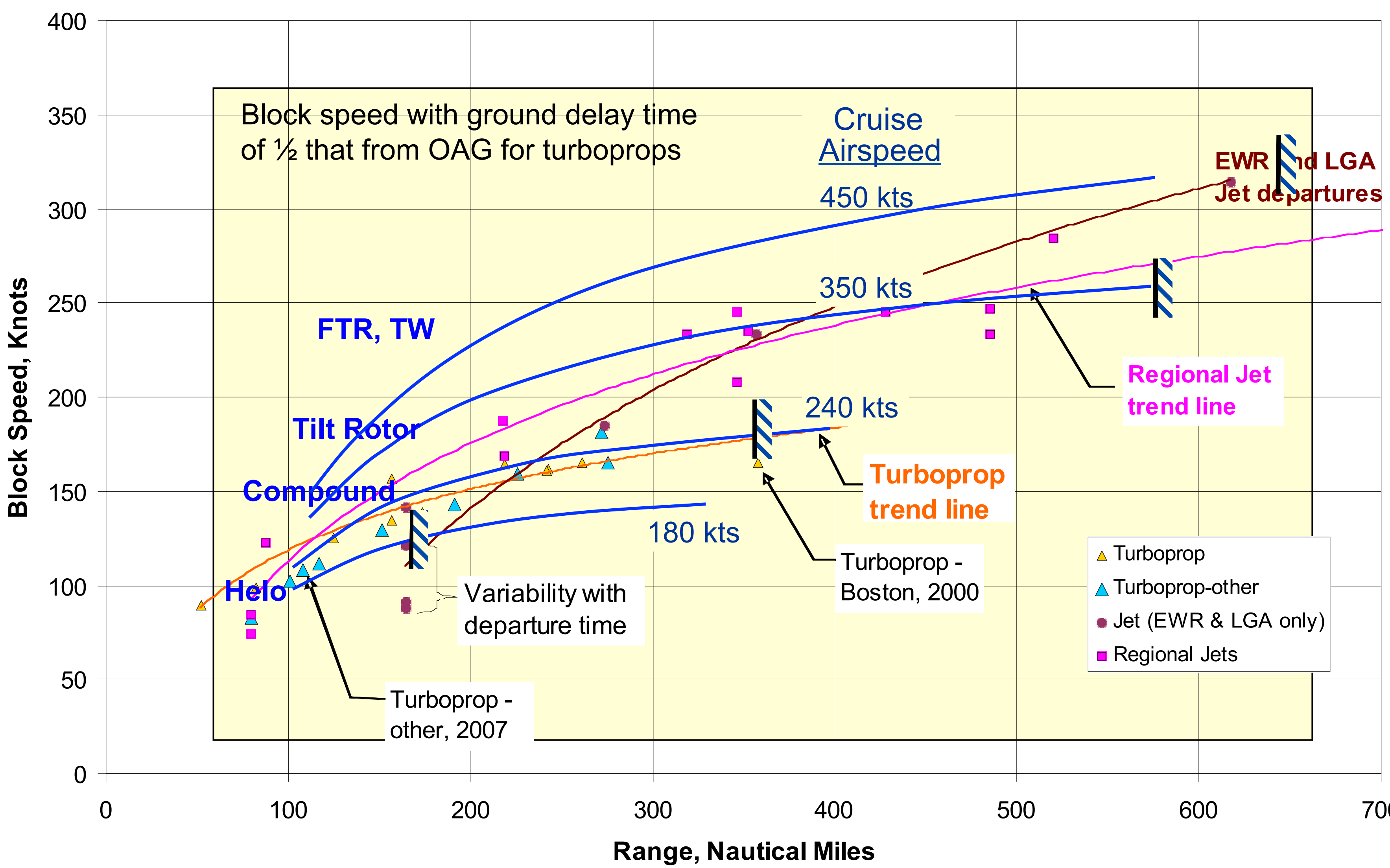


Looking at Operating Cost



Ref: NASA CR-214594, June 2009

The Rationale for Range



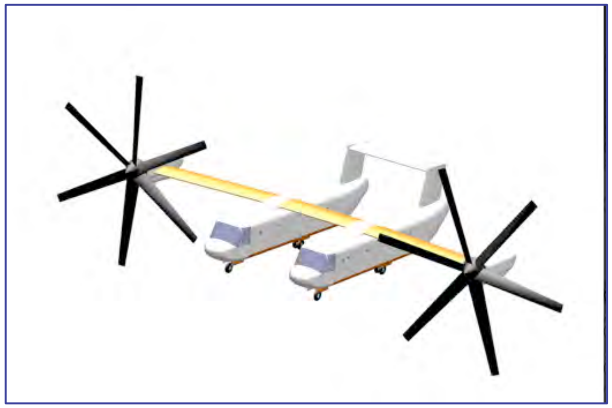
Ref: NASA CR-214594, June 2009

Large Civil Tiltrotor 2nd Gen (LCTR2)

- NASA's notional high-speed configuration
  - Use to model configuration capabilities in the Airspace
  - 90 passengers, 300 knots cruise speed, 1000 nm range (nominal)
  - Hover tip speed 650 fps / cruise tip speed 350 fps

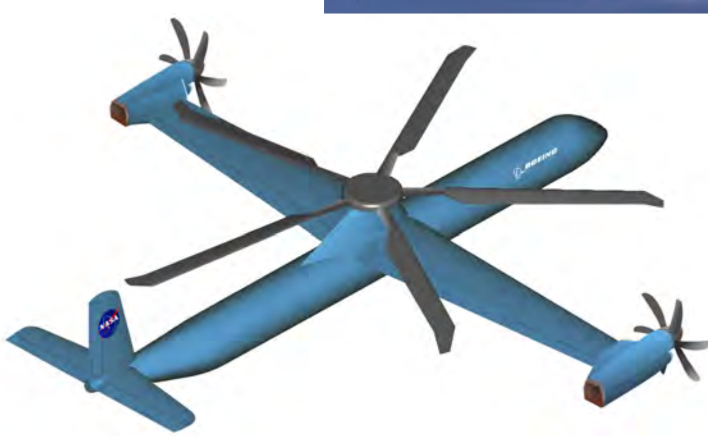
Reference: Acree, C. W., Hyeonsoo, Y., and Sinsay, J. D., "Performance Optimization of the NASA Large Civil Tiltrotor," NASA TM-2008-215359.

Advanced Aircraft
Performance, speed, payload, efficiency



JMR…

UAS…



FVL…

Primary Focus on Five Technical Challenges

- **Integrated Aeromechanics/Propulsion System (IAPS):** Develop and demonstrate technologies enabling variable-speed rotor concepts
  - **Goal**: 50% main rotor speed reduction while retaining propulsion efficiency
  - **Benefits:** very high-speed, efficient cruise; efficient hover; reduced noise, increased range
- **Actively-Controlled, Efficient Rotorcraft (ACER):** Simultaneously increase aerodynamic efficiency, control dynamic stall, reduce vibration, reduce noise
  - **Goal**: 100 kt speed improvement over SOA; noise contained within landing area; 90 pax /10 ton payload
  - **Benefits**: very high-speed, efficient cruise; efficient hover; reduced noise; improve ride quality
- **Quiet Cabin (QC):** Reduce interior noise and vibration
  - **Goal**: Internal cabin noise at level of regional jet with no weight penalty
  - **Benefit**: passenger acceptability; increased efficiency through weight reduction
- **NextGen Rotorcraft:** Foster, develop and demonstrate technologies that contribute to the commercial viability of large rotary wing transport systems in NextGen.
  - **Goal**: mature technologies (icing, crashworthiness, condition based maintenance, low noise flight operations, damage mitigation, etc) needed for civil, commercial operations
  - **Benefit**: enables vehicle acceptability for passengers and operators
- **High Fidelity Validated Design Tools**: Develop the next generation comprehensive rotorcraft analysis and design tools using high-fidelity models.
  - **Goal:** first-principles modeling in all disciplines; ensure design tools are hardware flexible and scalable to a large numbers of processors
  - **Benefit:** Reduce design cycle time and cost of NextGen rotorcraft; increase confidence in new concept design

SRW Research Approach

Three main paths to accomplish research:

- NASA in-house research

- Research with partners (Other Government Agencies, Industry, University)

- Sponsored research proposals through NASA Research Announcement (NRA)

Investment Strategy

- Invest in fundamental technologies that contribute to Technical Challenges
- Invest in some technologies that are not directly tied to goals, but have possibility
- Invest in facility and measurement capability infrastructure for unique rotary wing problems
- Leverage partnerships where possible
- Maintain workforce stability

Process for Determining/Updating Content

TOP DOWN (PI/PM/PS/SME)
PORTFOLIO DIRECTION
•Policy directions
•Portfolio balance (start/stop)
•Consider stakeholder input
•Robust technical roadmap

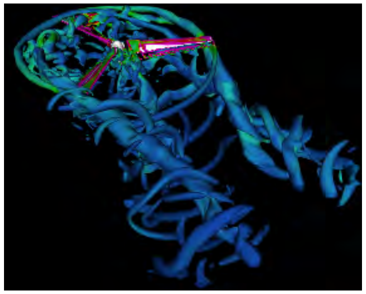
BOTTOMS UP (Researchers, line management)
•Recommendations during annual project planning
•Recommendations throughout year

Define specific investment criteria given limited resources (Project Management Decision)

- Does the technology apply specifically to rotorcraft?
- Is the research likely to be addressed in any other project or by any partner?
- Does the research contribute to SRW Technical Challenges?
- Is there a wide community of users interested in the technology?
- Does SRW have enough critical mass and budget to make significant progress in the area?

Execute SRW Plan
•Milestones
•Monthly Discipline Reporting
•Quarterly Project Reviews
•NRA Reviews
•Program Reviews

Subsonic Rotary Wing Project Team



SRW Project Summary

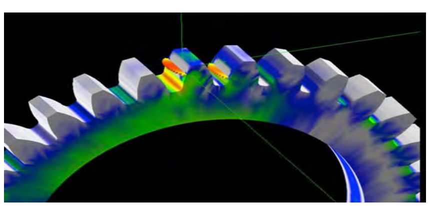
~133 work/years (108 CS / 25 Contractor)
~ $26M per year (includes salary)
Work across 3 NASA Centers

Ames Research Center
~40 work/years

- Aeromechanics
- CFD
- Flt Dyn & Ctrl
- Acoustics
- Exp Capability

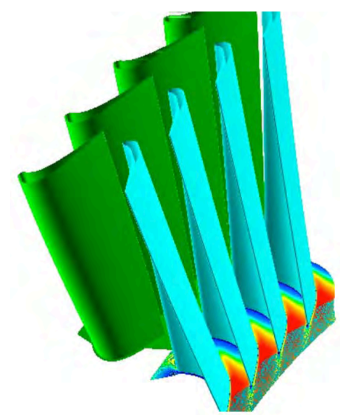
Langley Research Center
~48 work/years

- Acoustics
- Aeromechanics
- Exp Capability
- CFD
- Crashworthiness
- Materials
- Durability

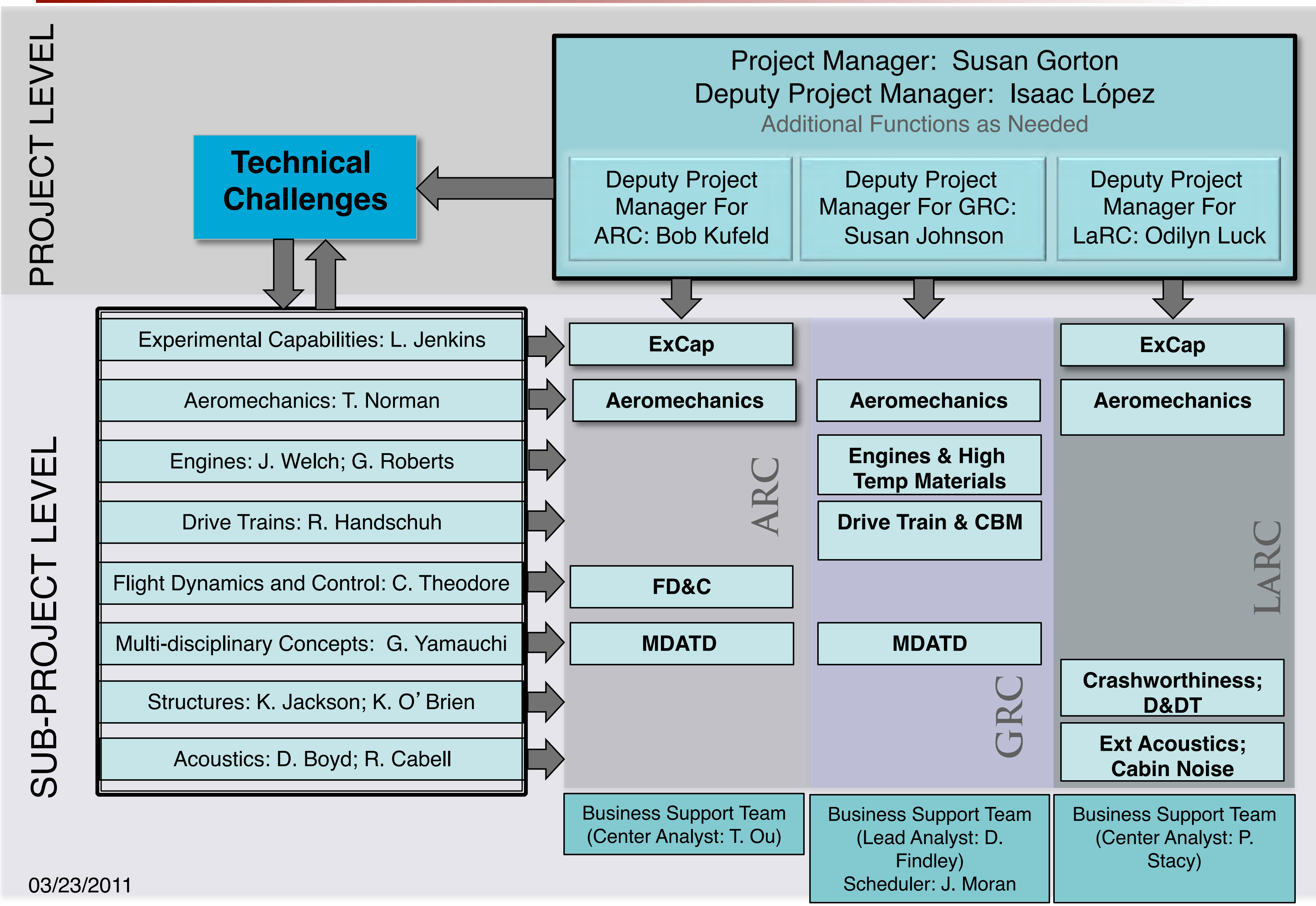


Glenn Research Center
~45 work/years

- Drive Train
- Turbomachinery
- Icing
- System Analysis
- CBM
- High Temp Materials
- Mechanical Components



SRW Project Organization



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SRW Major Facilities

SRW Project Summary

~133 work/years (108 CS / 25 Contractor)
~ $26M per year (includes salary)
Work across 3 NASA Centers

Glenn Research Center

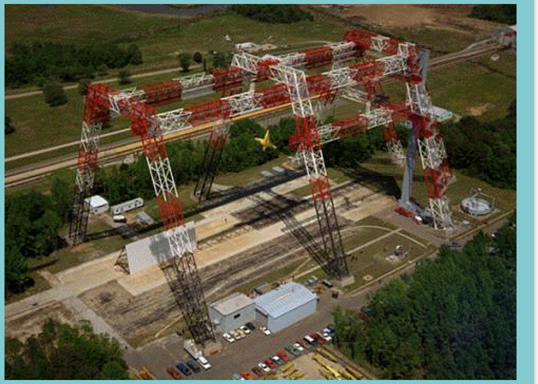
- Engine Component Research Lab
- Compressor Test Facility (CE-18)
- Transmission Test Facilities (ERB)
- **Icing Research Tunnel**

Ames Research Center

- National Full-Scale Aerodynamics Complex (NFAC)
- Supercomputing Complex (NAS)
- **Vertical Motion Simulator**

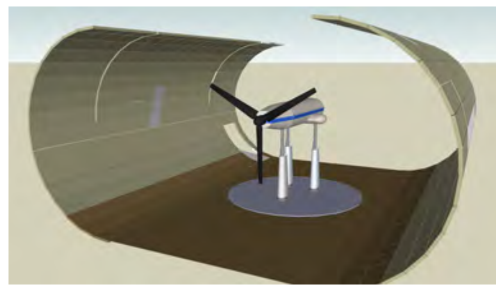
Langley Research Center

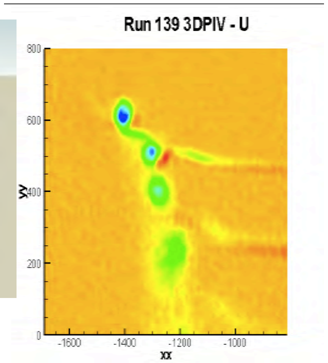
- 14- by 22-Foot Subsonic Tunnel
- Transonic Dynamics Tunnel
- **Landing and Impact Research**
- Structural Mechanics Lab

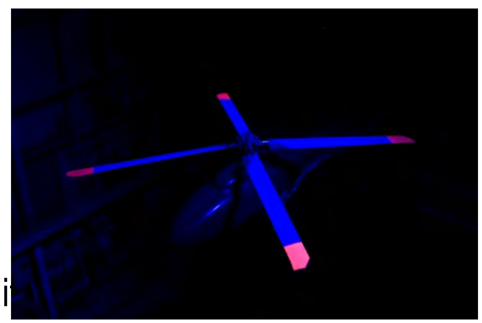


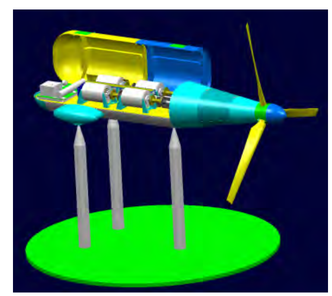
SRW Investment in NASA Facilities, 2006-2011

- National Full Scale Aerodynamics Complex, NFAC
  - Optical measurement technology
  - Blade deformation measurement capability
  - Retroreflective Background Oriented Schlieren (RBOS)
  - Titlrotor Test Rig**
- 14- by 22-Foot Subsonic Tunnel
  - New acoustic foam and traverse system
  - New instrumentation interface racks and A/D systems*
  - Upgrade and refurbish Laser Velocimeter system
  - Unsteady Pressure Sensitive Paint capability*
  - Large Field of View Particle Image Velocimetry*
- Transonic Dynamics Tunnel
  - Blade deformation measurement system*
- Drive Train Facilities
  - New windage research rig*
  - New variable/multi-speed transmission test rig*
  - New spur gear fatigue test rig*
- Turbomachinery Test Facilities
  - Refurbished T700 engine*
  - CE-18 (small compressor test facility) upgraded capabili
- Upgraded flight acoustic measurement capability*





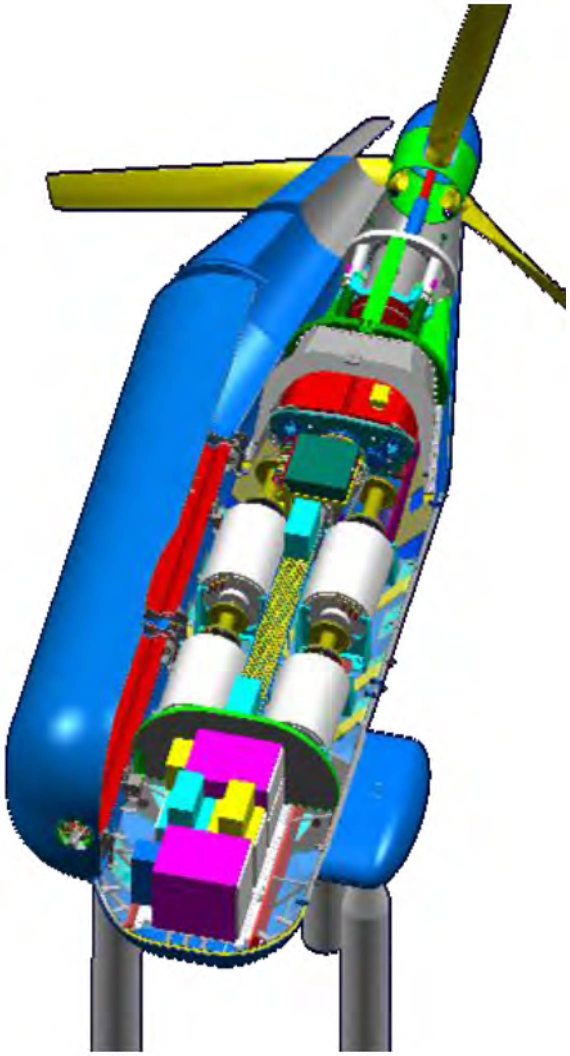




**partnership with Army*
***partnership with Army and Air Force*

TiltRotor Test Rig (TTR)

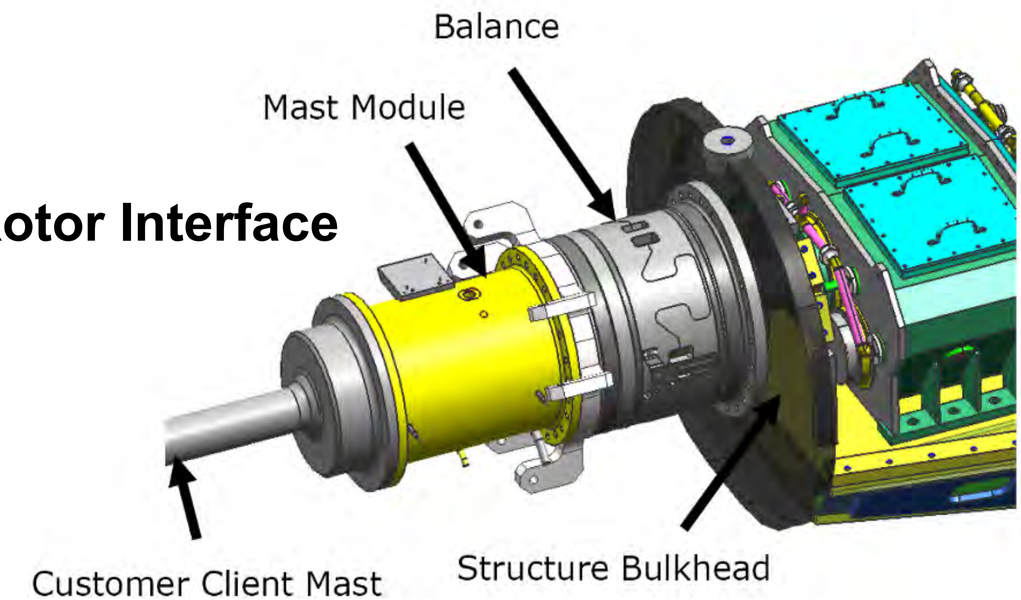
Integrated System Design



$11M ARRA directed to Rotary Wing Technology

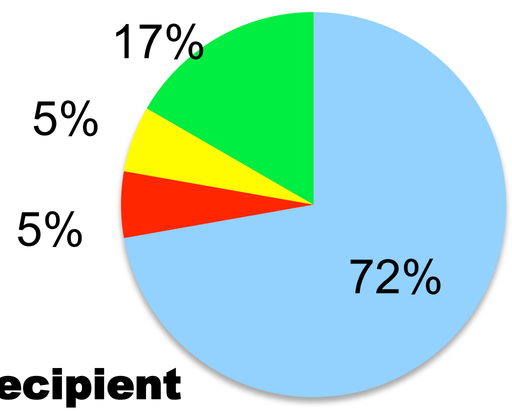
- Investment in restoring large-scale tiltrotor testing capability for NFAC
- Detailed design and fabrication started. Delivery of rig expected Oct 2011. Blades to follow in 2012.
- Joint investment with DOD/Army, Air Force

Client Rotor Interface

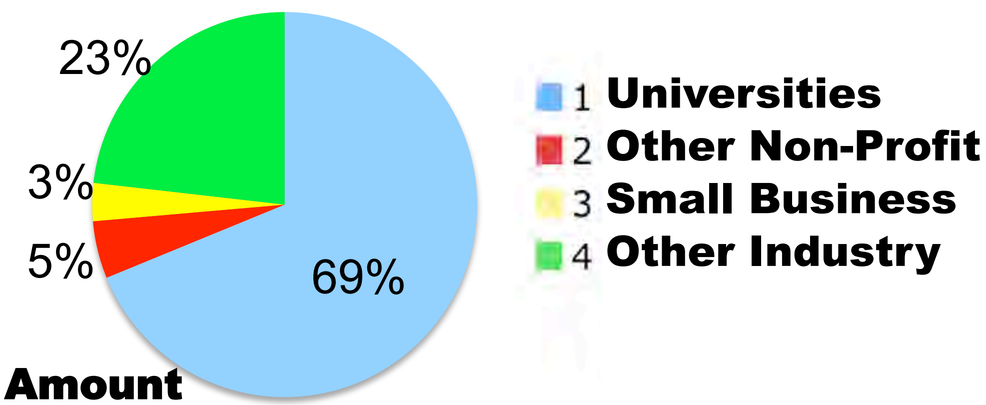


NASA Research Announcement (NRA)

NRA Round	Universities Number (Total Award Value)	Other Non-Profit Number (Total Award Value)	Small Businesses Number (Total Award Value)	Other Industry Number (Total Award Value)
Round 1 (FY06/7)	10 ($6.147M)	2 ($0.886M)	0	0
Round 2 (FY07)	10 ($3.809M)	0	1 ($0.450M)	2 (0.855M)
Round 3 (FY08)	4 ($1.229M)	0	1 ($0.136M)	3 ($2.370M)
Round 4 (FY09/10)	2 ($1.464M)	0	0	1 ($1.039M)
Total	26 ($12.649M)	2 ($0.886M)	2 ($0.586M)	6 ($4.264M)



By Recipient



By Amount

Technical Challenges (Level 2): *DRAFT*

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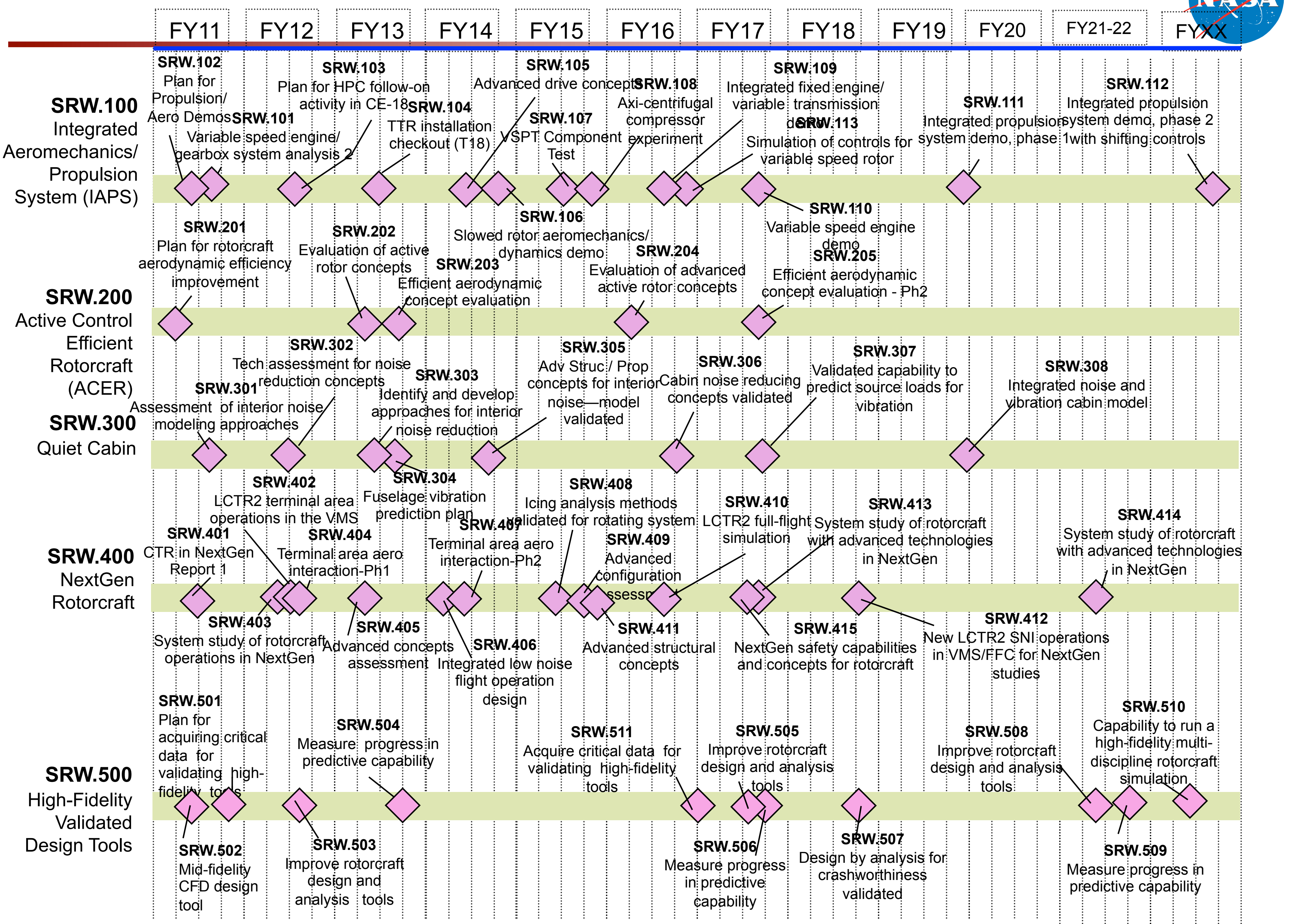
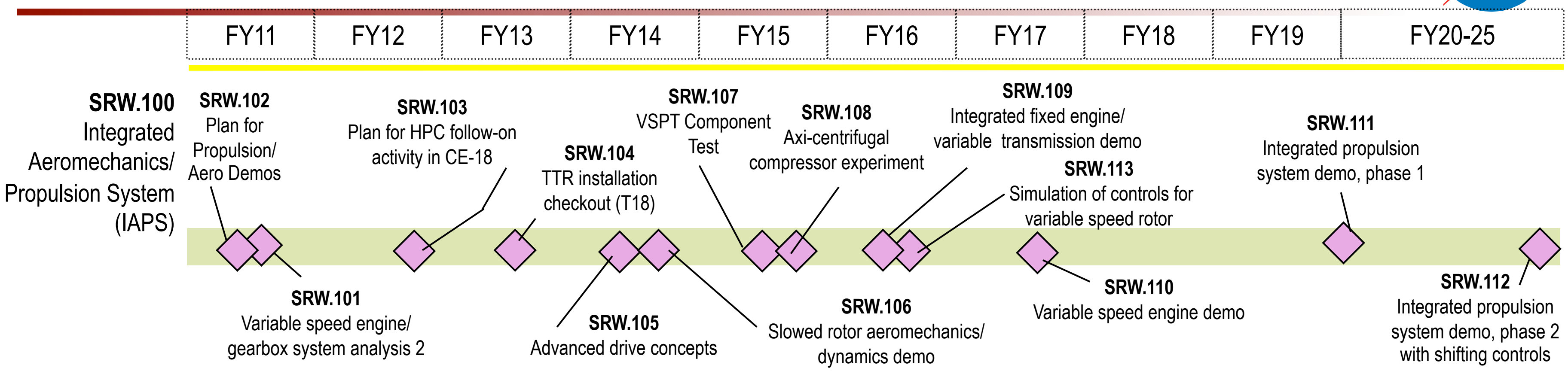
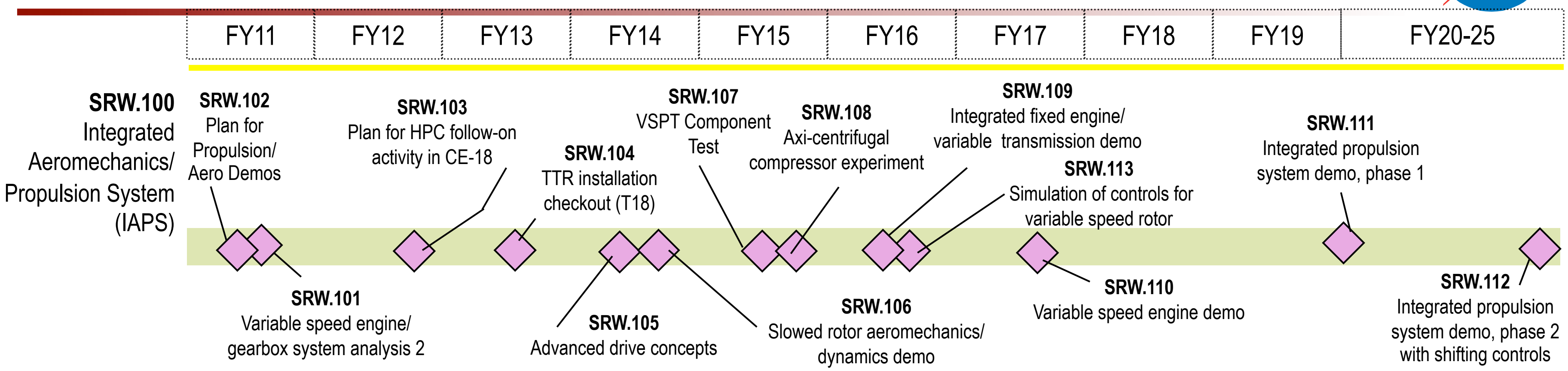


Integrated Aero/Propulsion System (IAPS) (FY25)



What what are we trying to do?	Why?	How is it done today, and what are the limits of current practice?	What is new in our approach?	What are the payoffs if successful?
Demonstrate (ground test) a variable speed (50% reduction from hover to cruise) rotor	• Ability to use variable speed as a design parameter is crucial for enabling high-speed civil rotorcraft for NextGen • Variable speed expands design space • Variable speed enables efficiency in hover and high-speed cruise	• Always single speed transmission; limited variable rotor speed via changes in engine speed • No demo of engine & transmission for variable speed operations • No integrated platform • No aeromechanics/propulsion test • Only 10-15% variation in rotor speed for existing rotorcraft	• Integrated components in a wind tunnel test • Control system design that integrates propulsion, rotor, flight controls • Engine gearbox speed reduction • Efficient turbomachinery operation at variable speeds (power turbine and compressor) • Validate transmission/ engine shifting capability for cruise/hover rotor speed changes	• Variable speed rotorcraft (e.g. LCTR2) can have significant positive impact on NextGen • New capability enabled to improve rotorcraft speed 50-70% • New national capability for testing integrated engine/drive system

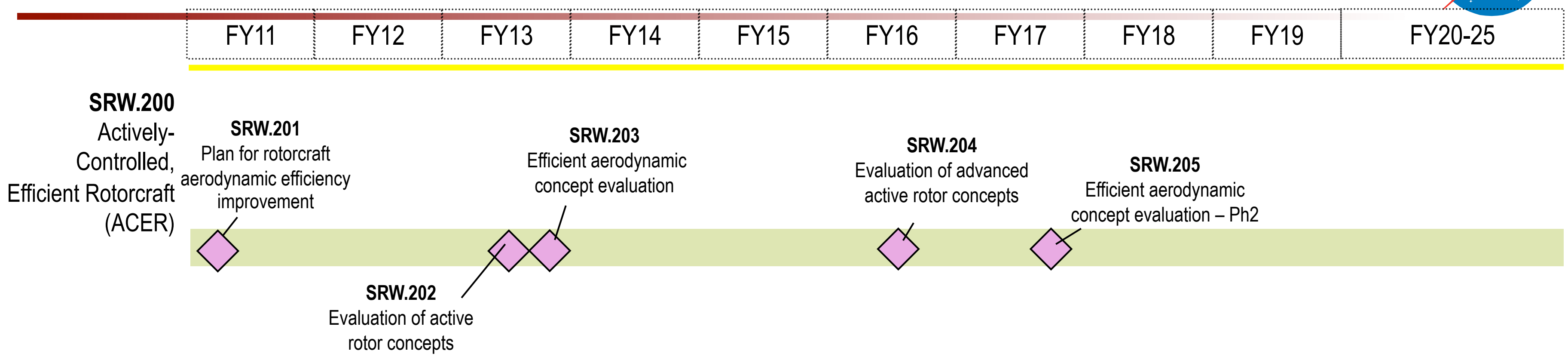
Integrated Aero/Propulsion System (IAPS) (FY25)



Includes

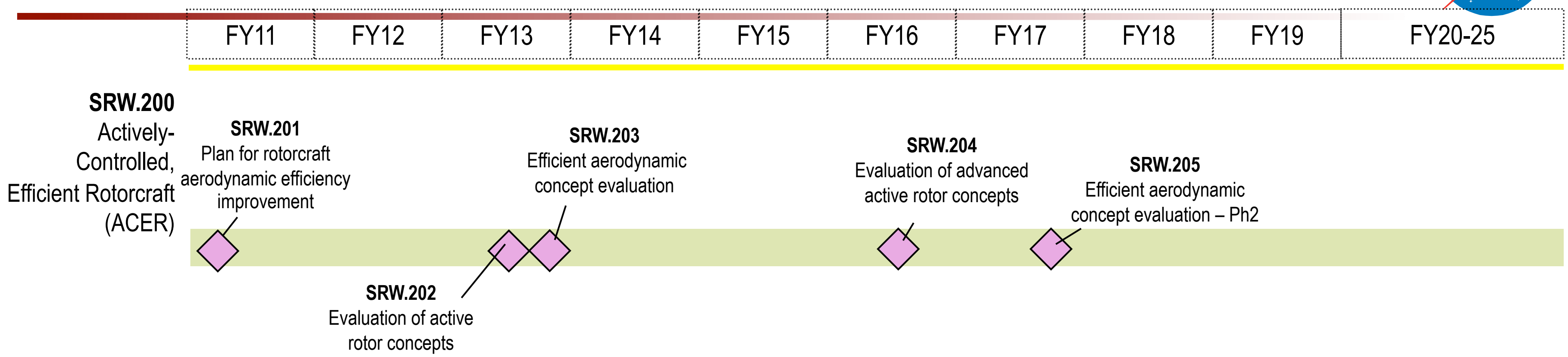
- system analysis of engine/drive train system
- engine analysis for compressor/turbine system requirements
- variable speed engine demonstration
- variable/multi speed drive system design and experimental validation: demonstration of shifting
- gear windage experiment and CFD
- combined engine /drive train demonstration
- evaluation of aero performance at reduced rpm
- determination of aero/dynamic interaction and torque during rpm change
- evaluation of propulsion system dynamics during rpm change
- demonstration of combined aero/propulsion system
- high temperature material concepts for engine efficiency

Actively-Controlled, Efficient Rotorcraft (ACER) (FY17)



What what are we trying to do?	Why?	How is it done today, and what are the limits of current practice?	What is new in our approach?	What are the payoffs if successful?
•Evaluate active rotor technologies and develop methodologies to predict their effects	• Extend flight envelope and capabilities of current rotorcraft and maximize the capabilities of rotorcraft for future civil and military missions	• Passive devices; currently limited to things like swept tips, etc. •Cannot predict performance and loads; current prediction methods are starting now to get reasonable predictions of conventional designs	• Examination of active control technologies in an integrated way (aeromechanics + acoustics + FD&C) • A systematic evaluation of several active rotor technologies with corresponding computational method development and evaluation	•Active devices that could be used in a practical manner •Higher-performance, quieter rotor systems • Extensive databases with aero performance, acoustic, structural, and flowfield data for validating analysis tools

Actively-Controlled, Efficient Rotorcraft (ACER) (FY17)



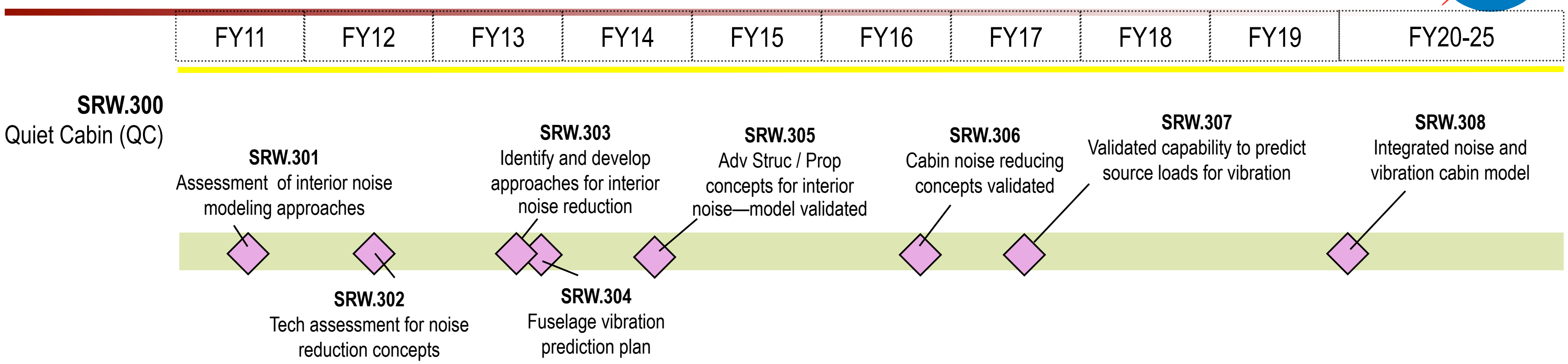
Includes

- SMART rotor (wind tunnel test completed)
- IBC, data reduction and analysis on-going
- Active Twist Rotor—high performance design, possibly an airfoil design task supporting this
- Active flow control for fuselage drag reduction (efficiency)
- Active flow control concepts (SSAR) and possibly actuators in rotating system
- Acoustics/noise research for external noise
- Maneuver acoustics

Partnership Opportunities

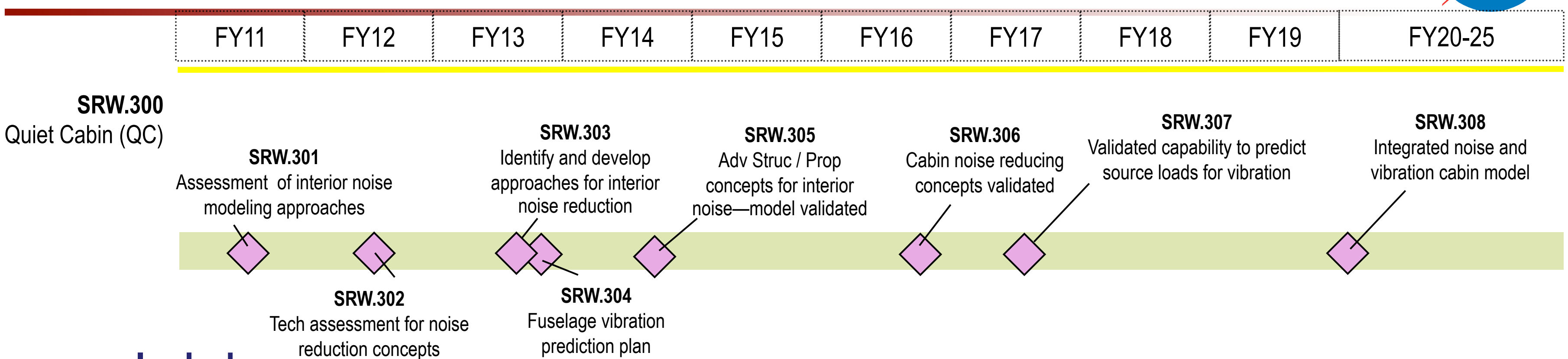
- Flight test of SMART rotor for maneuver acoustics
- Active Flow Control Rotor concepts/demonstration
- Demonstration (semi-span) of efficient cruise rotorcraft
- Validation of optimization methodology

Quiet Cabin (QC) (FY20)



What what are we trying to do?	Why?	How is it done today, and what are the limits of current practice?	What is new in our approach?	What are the payoffs if successful?
• Develop a tool-set to analyze engine/ transmission noise propagated through the structure into a representative cabin	• Need a capability for predicting noise transmission through advanced structures and provide guidance during aircraft design on interior noise impact of transmission and supporting structure design	• Integrated analysis does not exist • There is no capability today to correlate changes in transmission/gearbox noise levels with expected changes in cabin noise levels. State of the art is to fly and fix hardware.	• Develop a test rig (transmission + representative cabin) capable of varying transmission noise using interchangeable gears with interchangeable structural panels • Integrate separate analyses into a comprehensive toolset	• Quieter cabins w/o weight penalty • Capability to model vibroacoustic implications of variable-speed rotor • Passenger acceptance and comfort • New capability to trade noise reduction technologies

Quiet Cabin (QC) (FY20)



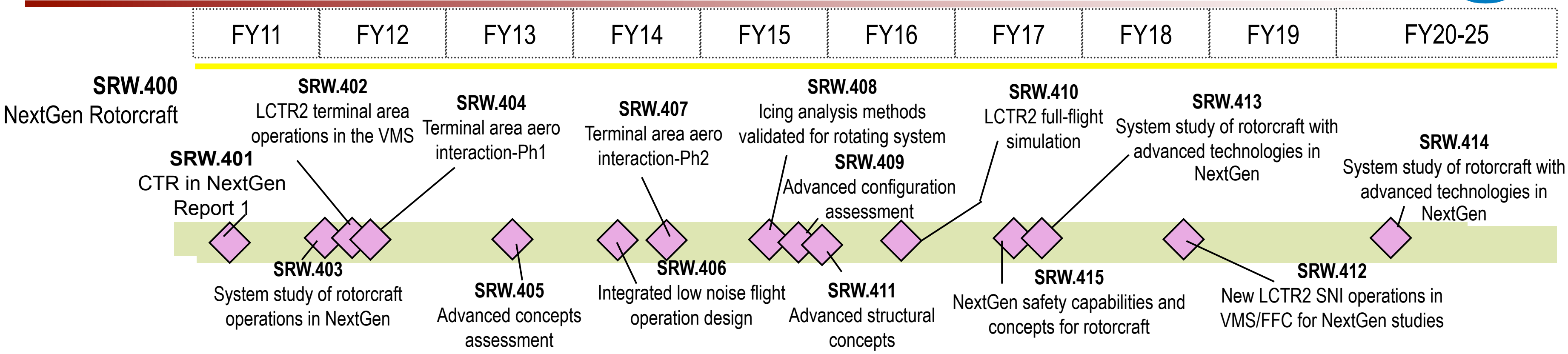
Includes

- new models for structural noise transmission
- new techniques for controlling structural noise transmission
- development of low-noise transmission mounts, gears, transmission cases, bearings
- development of new structural components for noise absorption
- development of new lightweight, acoustically absorbing material
- assessment of passive vs active benefits
- integration/ development of analysis tools for components/subsystems
- vibration reduction from aeromechanics

Partnership Opportunities

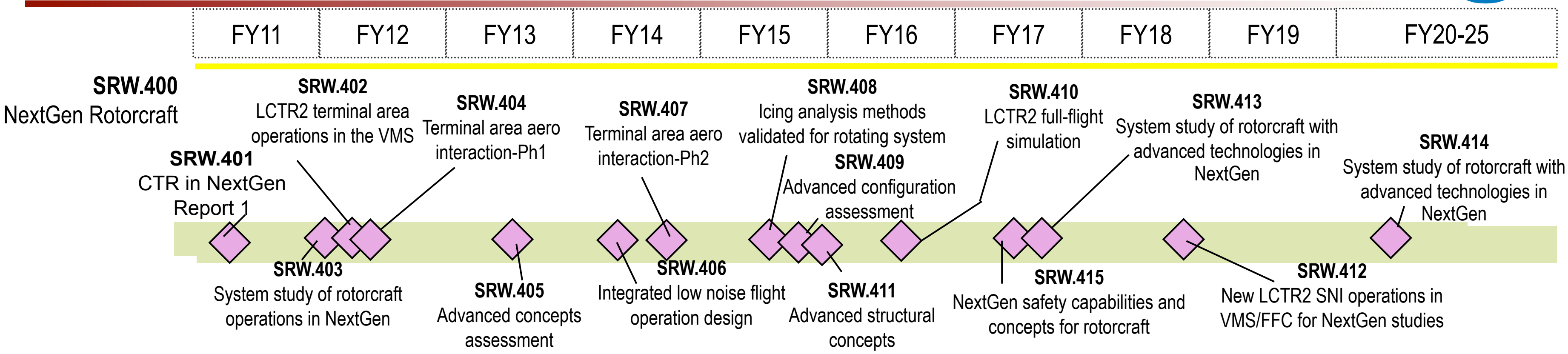
- investigation of low frequency noise effects (plan developed under NRA)
- integration of techniques and components experimentally
- development of noise integration test rig (cabin simulator with transmission input)

NextGen Rotorcraft (FY21)



What what are we trying to do?	Why?	How is it done today, and what are the limits of current practice?	What is new in our approach?	What are the payoffs if successful?
• Foster, develop and demonstrate technologies that contribute to the commercial viability of large rotary wing transport systems in NextGen	• NASA Aeronautics and SRW goals are tied to the National R&D Plan and the national goals to support NextGen as a national priority. Advanced rotorcraft capabilities are necessary for rotorcraft to play a significant role in the future air transportation system	• New capability. • There are no large (>20) passenger transport rotorcraft in service today • Transport rotary wing limited by noise, speed, cost, payload, efficiency, safety and passenger acceptance issues. • Operations in the airspace system need to be developed	• Address significant commercial requirements for a large, transport rotorcraft	• Enhanced air transportation system capacity. • Time-sensitive and fuel efficient use of rotorcraft. • Alternative air transportation mechanism for designated service access to major hub airports (connection to long-haul system)

NextGen Rotorcraft (FY21)



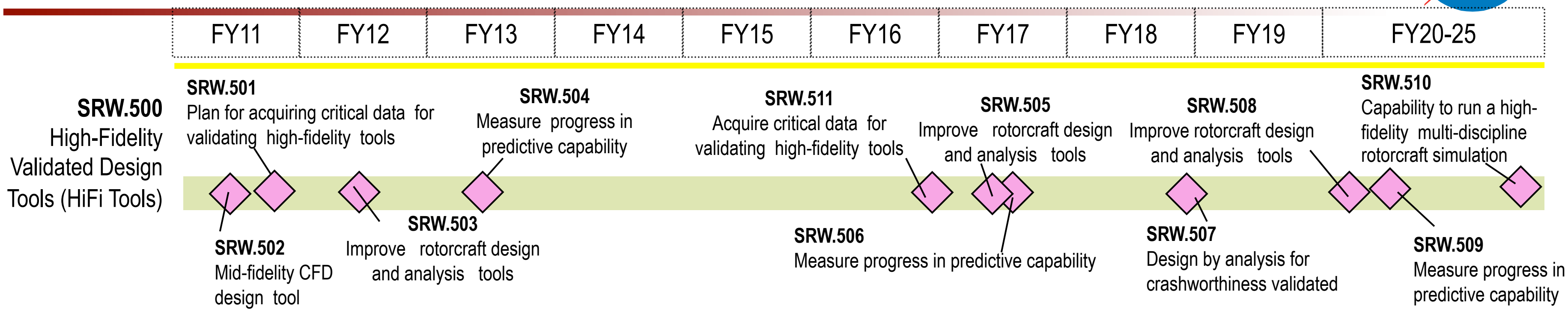
includes

- operations in the NextGen airspace environment
- low-noise operations for community acceptance
- ride quality/ handling qualities to acceptable passenger and pilot comfort levels
- icing technologies to support all-weather operations
- crashworthiness design for survivability and safety
- reduced maintenance issues through validation of CBM methods
- structural airframe improvements in durability and damage tolerance

Partnership Opportunities

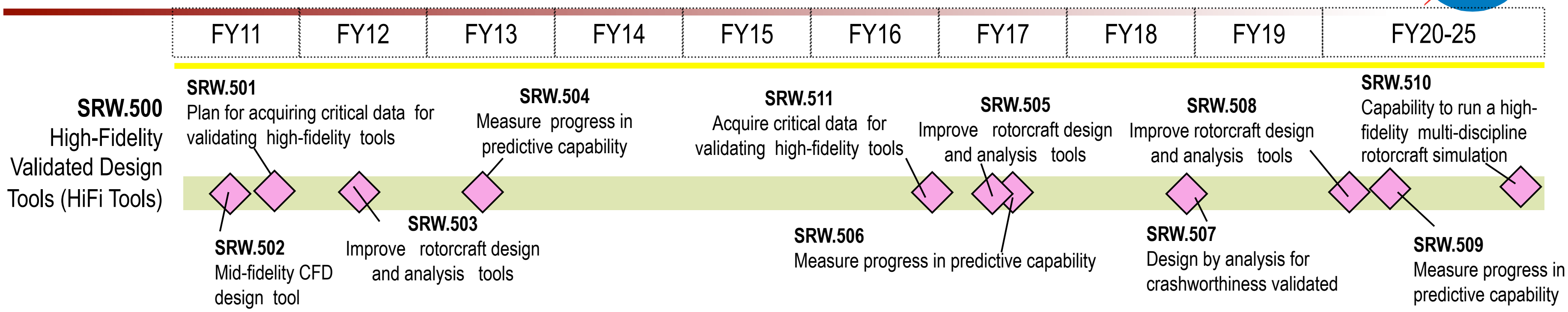
- multi-aircraft simulation of NextGen airspace operations
- powered rotor icing test capability for the Icing Research Tunnel (CRI TAJI)

High-Fidelity Validated Design Tools (FYxx)



What what are we trying to do?	Why?	How is it done today, and what are the limits of current practice?	What is new in our approach?	What are the payoffs if successful?
• Develop the next generation comprehensive rotorcraft analysis and design tools using high-fidelity models	• New rotorcraft developmental risk is too high and design cycle is too long • Designer needs higher fidelity tools earlier in the design cycle • High performance computing will require new design tool paradigms • Need modular suite of tools, consistent in fidelity, to analyze rotorcraft for all operating conditions for all disciplines	• Mostly uncoupled discipline analyses (aero, structures, propulsion, flight dynamics and control, acoustics); limited optimization • Analyses vary widely in accuracy • Restricted to certain configurations, flight conditions • Current low-fidelity/low-resolution tools are not efficient on new parallel computers—with rapidly evolving compute hardware, this is a dramatically worsening trend	• Aiming toward first-principles modeling in all disciplines • Insuring design tools are hardware flexible and scalable to a large numbers of processors • Working interfaces between codes from Aero and Propulsion; Structures and Acoustics; Acoustics and Propulsion • Facilitating closer collaboration between analysts and experimenters, resulting in better designed experiments and validation efforts	• Reduce design cycle time and cost of NextGen rotorcraft • Enable rotorcraft to fly as designed – safely and efficiently

High-Fidelity Validated Design Tools (FYxx)



includes

- structured CFD
- unstructured CFD
- optimization
- methods for crashworthiness prediction
- methods for propulsion analysis
- conceptual design tools
- new algorithm development
- new visualization methods
- new turbulence and transition model application
- experimental data for code validation

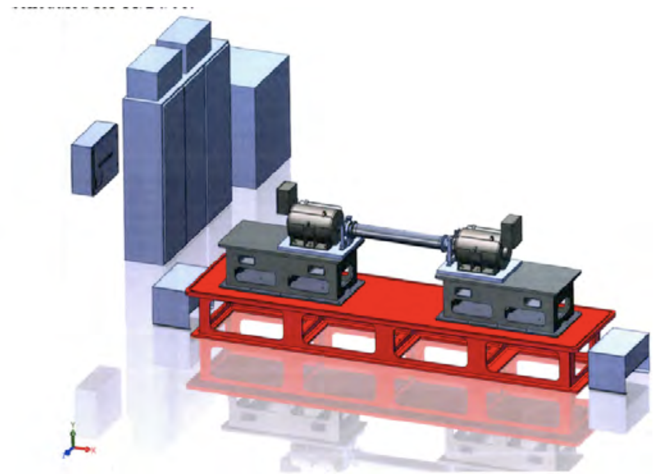
Partnership Opportunities

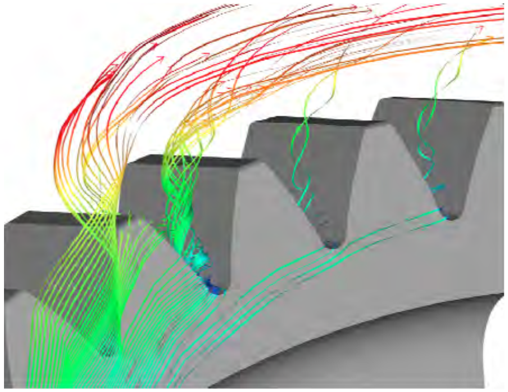
- HELIOS/ CREATE
- turbulence modeling
- unique data sets for validation

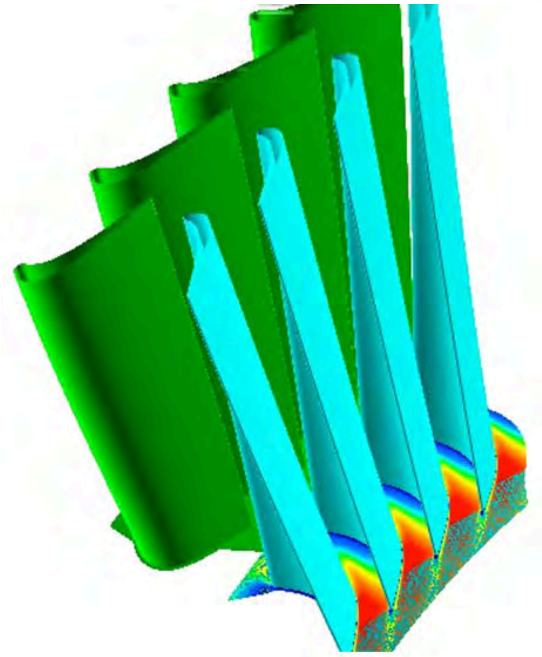
SRW Discipline: Propulsion

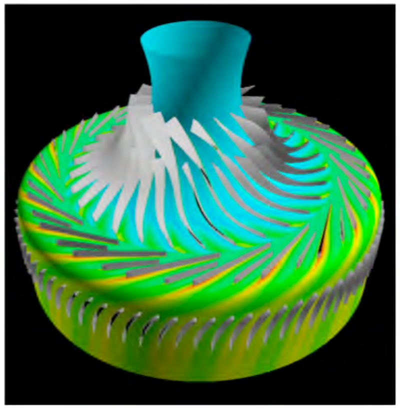
Advanced modeling tools/concepts essential to allow an engine/drive system to achieve a significantly larger speed range without sacrificing power and efficiency

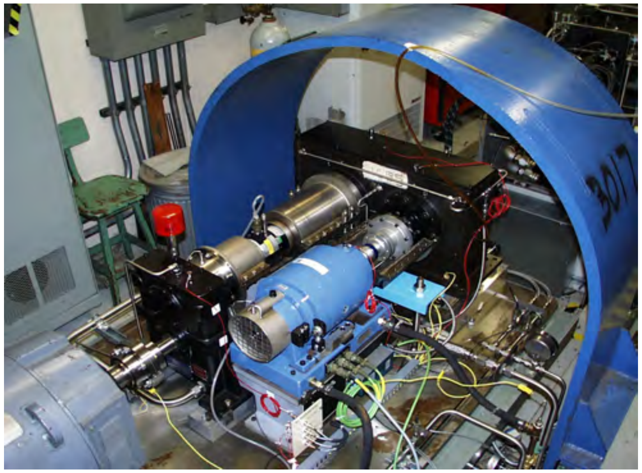
- High efficiency, multi/variable-speed drive systems
- Efficient, variable-speed turbomachinery







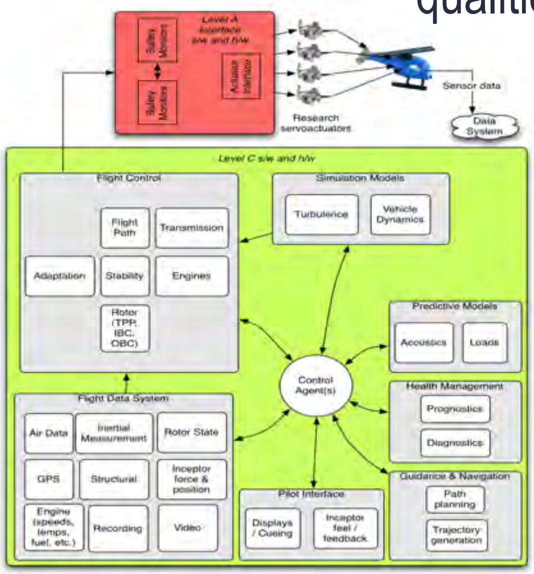




SRW Discipline: Flight Dynamics and Control

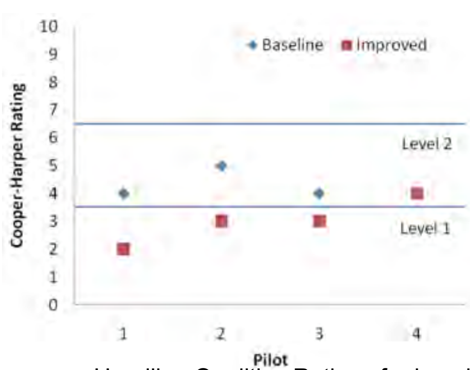
Flight dynamics and control research focuses on modeling, testing, and validating real-time control of integrated, advanced rotorcraft technologies with emphasis on handling qualities for large rotorcraft.

First-Principles Modeling



Vertical Motion Simulator
T-Cab with baseline inceptors

Validation



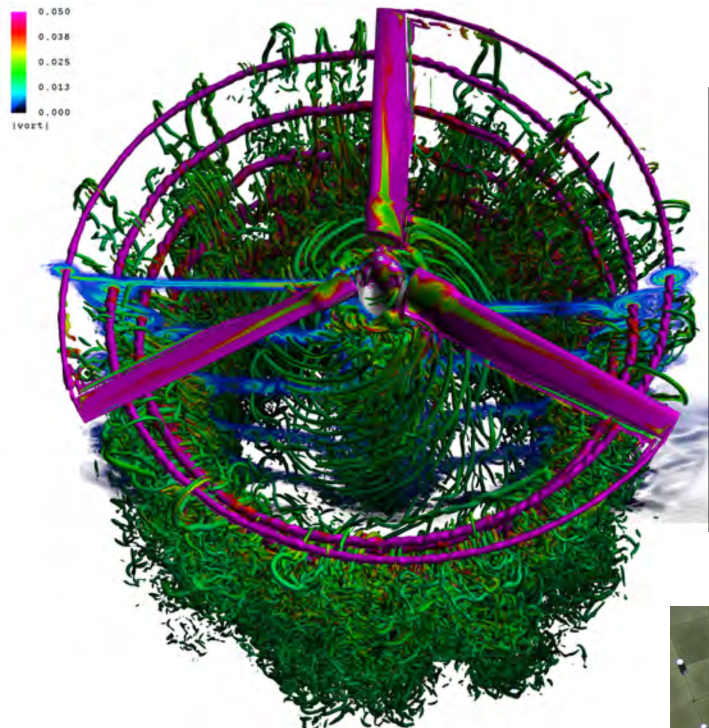
Handling Qualities Ratings for baseline and improved configurations

LCTR2 precision hover simulation

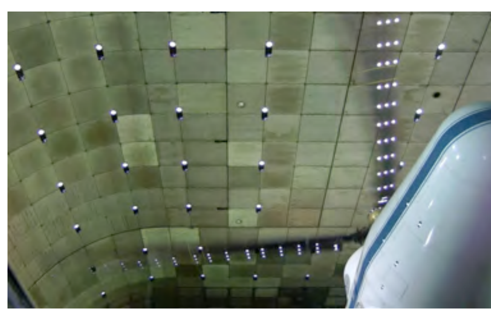
SRW Discipline: Aeromechanics

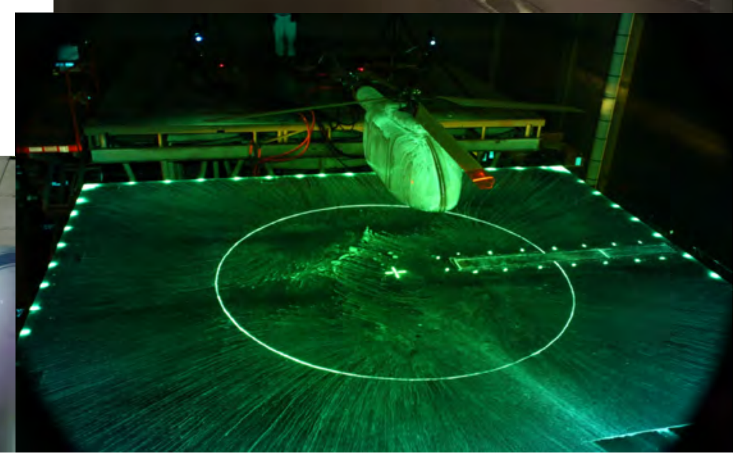
Rotorcraft aeromechanics research extends from first-principles modeling through testing and validation for isolated and multi-disciplinary phenomena. Particular emphasis on: active rotors (active flaps, active twist, IBC), active flow control, CFD modeling and coupling (structured and unstructured), icing

First-Principles Modeling



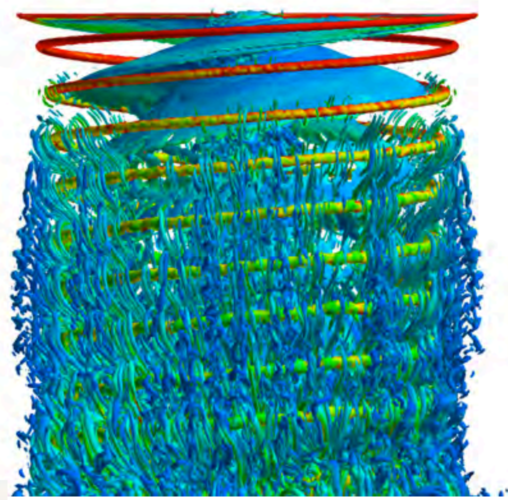
Testing

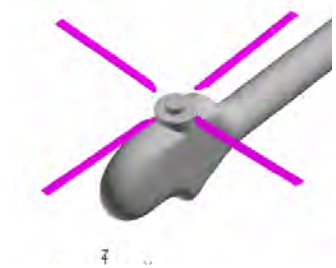


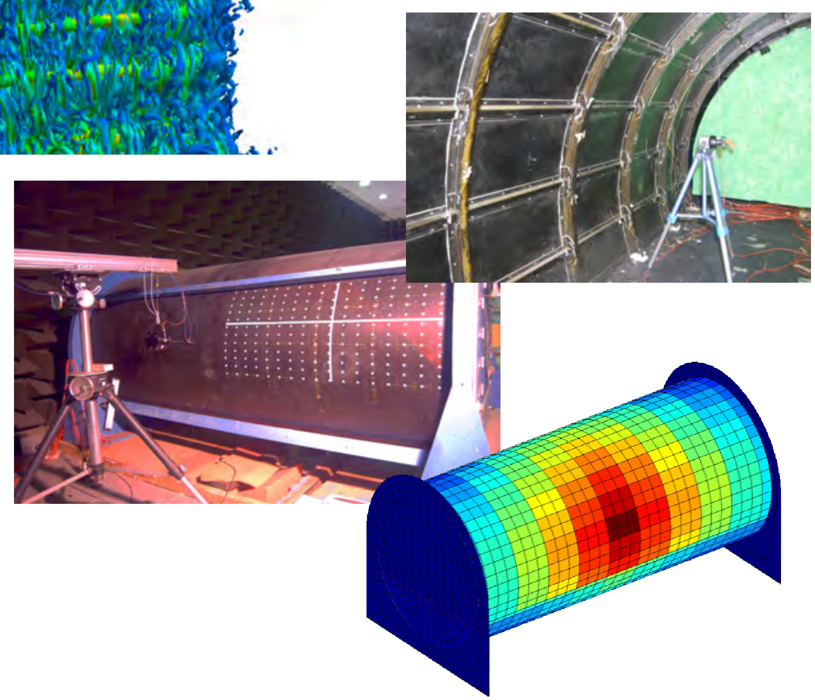


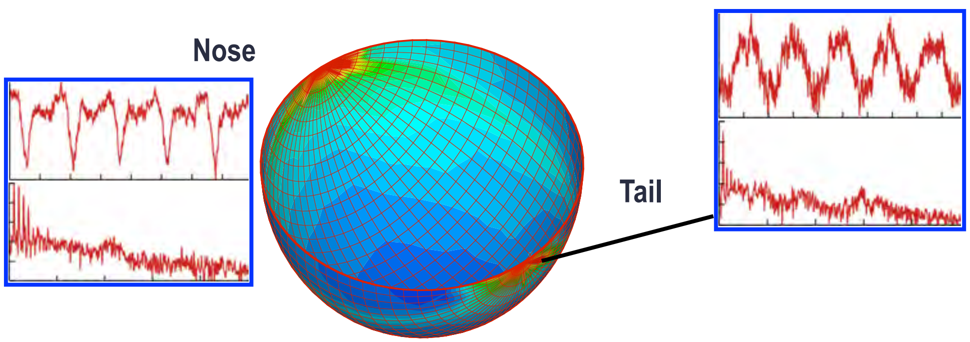
SRW Discipline: Acoustics

Rotorcraft acoustics research focus includes the study and control of source noise, interior noise, gear noise, community acceptance, low frequency effects, and concepts for low-noise operations



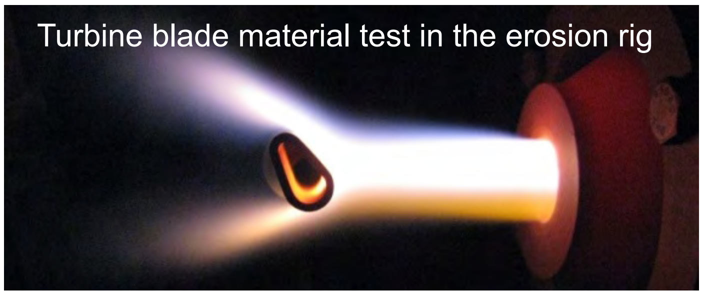


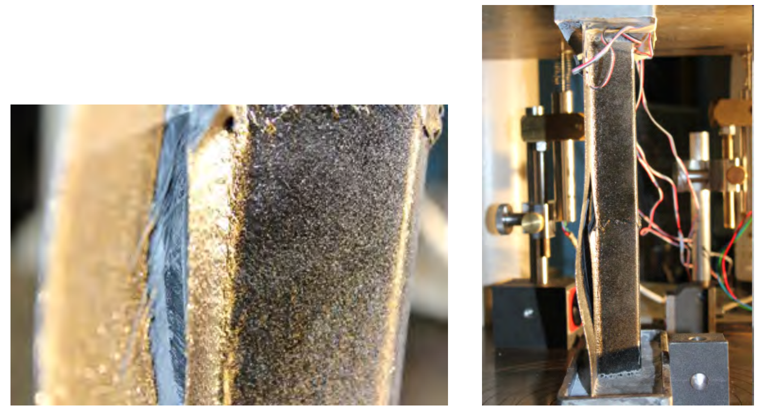


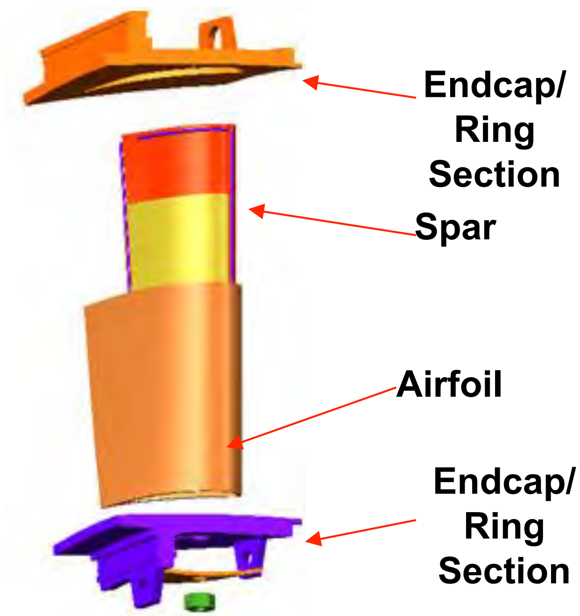


SRW Discipline: Material and Structures

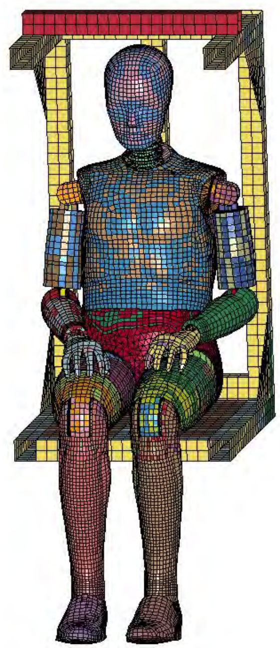
Materials and structures research focused on rotorcraft-specific issues in crashworthiness, advanced materials for airframes and engines, durability and damage tolerance


Turbine blade material test in the erosion rig


Post-failure pictures of imperfect specimen. Grey/blue zone under flange represents manufacturing defect.



Hybrid Vane for HPT


FTSS finite element model

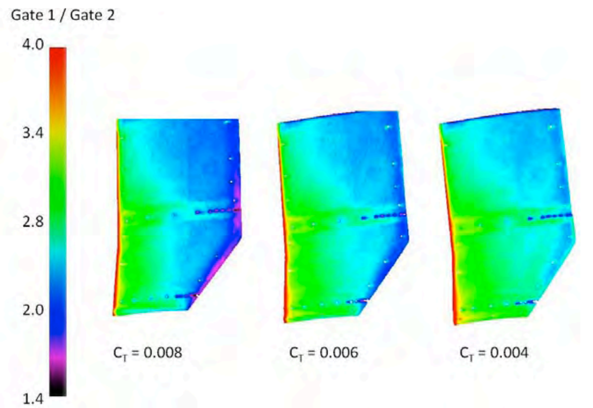

Crash Analysis Validation

SRW Discipline: Experimental Capabilities

Experimental Capabilities development is essential for validation of aeromechanics, acoustics, structural response, and propulsion fundamental methods

Large field rotor wake assessments

Representative porous polymer PSP data from a rotorcraft blade in hover



Deformed blade geometry

Blade Displacement

Targeted Primary NASA Rotorcraft Test Facilities

National Full-Scale Aerodynamics Complex

Transonic Dynamics Tunnel

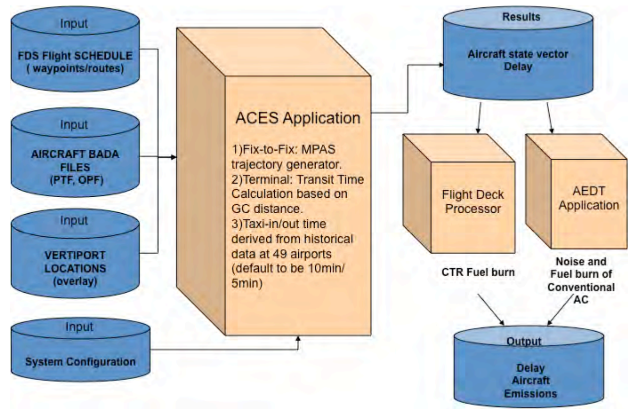
14- by 22-Foot Subsonic Tunnel

SRW Discipline: Multi-Disciplinary Analysis and Technology Development

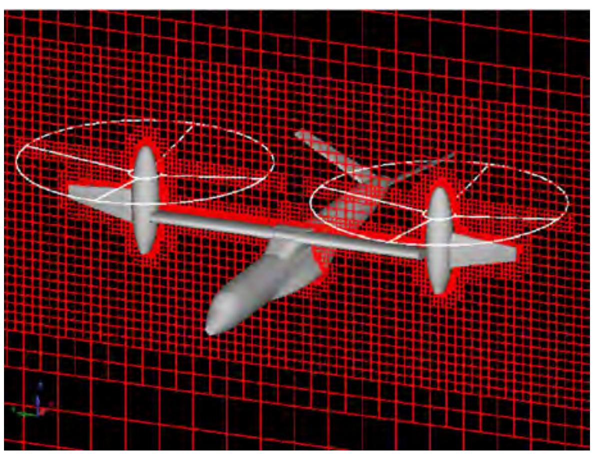
Provides a focal point for the integration of discipline technologies to guide fundamental research priorities. Analyses development at the system level and demonstrations of integrated components to enable advanced rotorcraft.

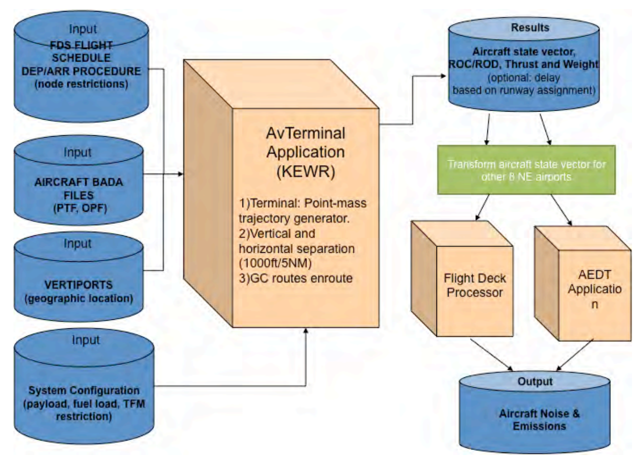
Elements

- Integrated Systems Technology Challenges
- Design and Analysis
  - Tools
  - Technology Assessments



"CTR in Next Gen Airspace" Simulation Framework



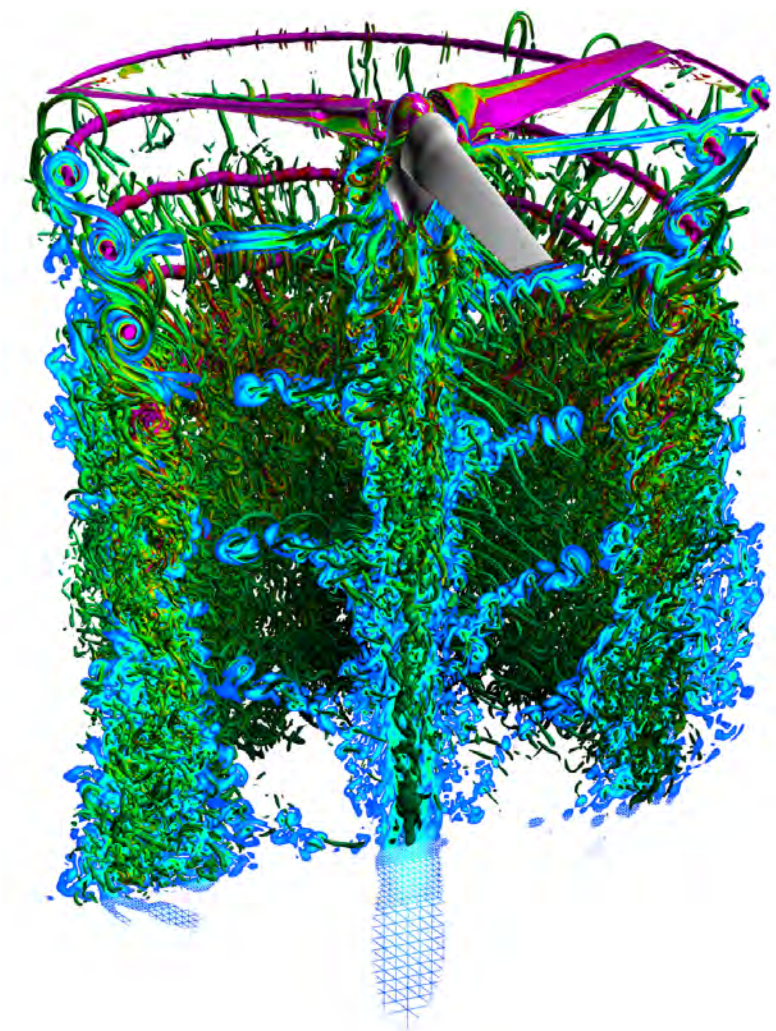


Formal Partnerships

- FAA, drive system health monitoring
- Army slowed rotor research
- JAXA active rotor prediction and test
- Army, JFTL/JMR
- Army, acoustic flight research
- Army, Active Twist Rotor
- Army, PSP, PIV and PMI
- Army, UTRC, advanced compressor research
- DARPA, MAR
- VLC/CRI, rotorcraft icing
- VLC/CRI, fatigue life methods
- ONERA, Active Flow Control on fuselage
- DLR, Active Stick Controller
- DLR, Rotor wake measurement techniques
- STAR (formerly HART III) ATR
- Bombardier/Learjet, interior noise
- University of Padua, Italy, trajectory optimization for low noise

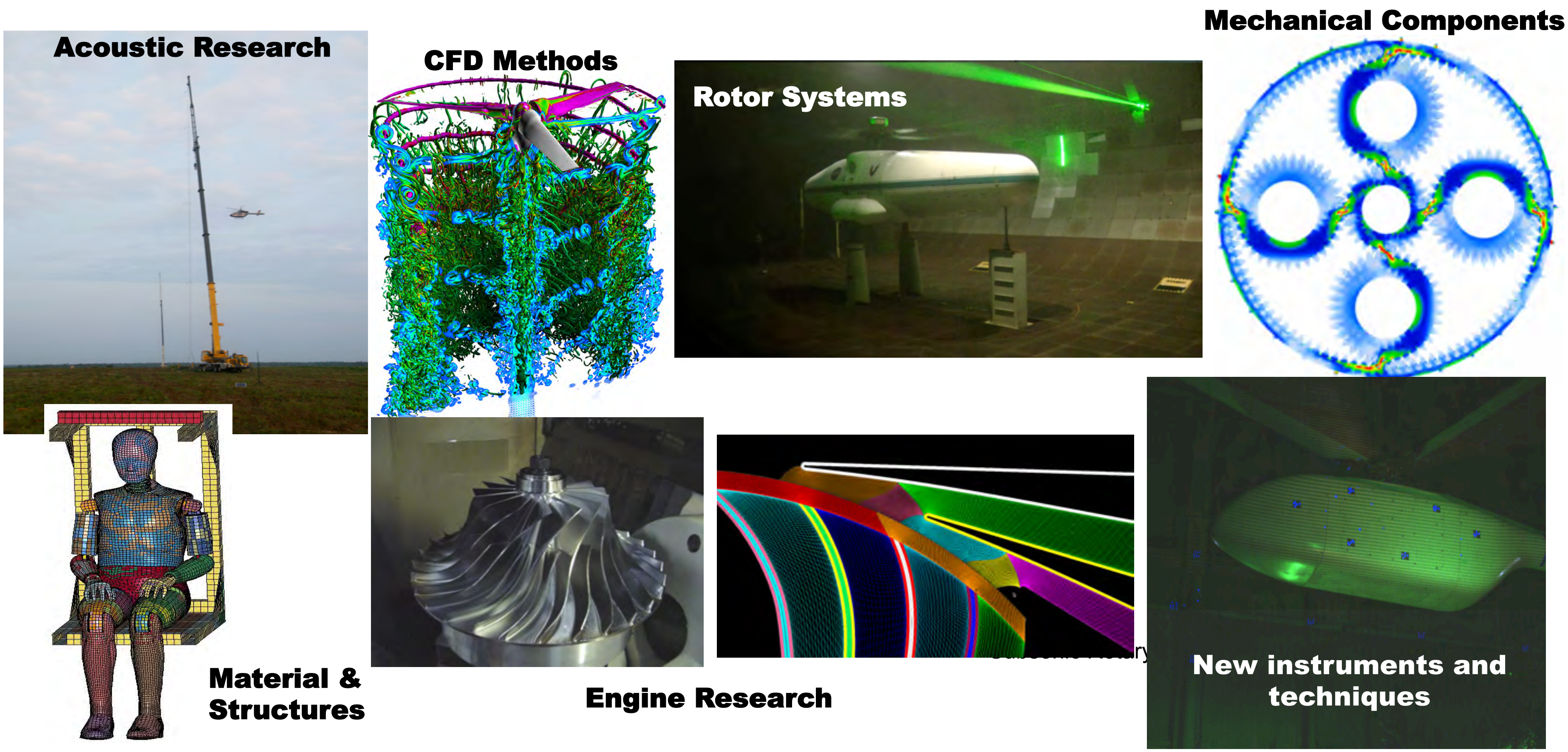
Upcoming Research Activities

- Complete testing of specimens under fatigue loading, April 2011
- Execute Active Flow Control and Pressure Sensitive Paint rotor test in 14- by 22-Foot Subsonic Tunnel in April 2011
- Initiate checkout of Variable Speed Transmission Test Facility, Summer 2011
- Execute joint advanced compressor research with UTRC under NRA in CE-18, Fall 2011
- Initiate acceptance testing of Tiltrotor Test Rig, Fall 2011
- Evaluate CFD improvements in aeromechanics, wake prediction, acoustic predictions, and crash predictions



Subsonic Rotary Wing (SRW) Project

Goal: Radically improve the transportation system using rotary wing vehicles by increasing speed, range, and payload while decreasing noise, vibration and emissions



SBIR support for SRW

Title/ Performer	Year/Phase
A&P Technology, SBIR Contract NNC10CA19C, “Composite Material for Rotorcraft Drive Systems	Phase 3
Lawrie Technology, Inc., Phase 2 SBIR Contract NNX09CA35C,“Fully Integral Flexible Composite Driveshaft Phase 2E award delayed due to Continuing Resolution	Phase 2E
Design Concepts for Cooled Ceramic Matrix Composite Turbine Vanes, N&R Engineering	Phase 2
10-1-A2.09-8157 ARC RotCFD: A Viscous Design Tool for Advanced Configurations, Sukra Helitek, Inc.	2010 Phase 1
10-1-A2.09-9076 LaRC Innovative Tools for Structural Diagnostics of Rotorcraft Fatigue Critical Composite Parts, Numerical Technology Company, LLC	2010 Phase 1
10-1-A2.09-9309 LaRC A Computational Tool for Helicopter Rotor Noise Prediction, D&P, LLC	2010 Phase 1
10-1-A2.09-9439 LaRC Real-Time, Maneuvering Flight Noise Prediction for Rotorcraft Flight Simulations, Continuum Dynamics, Inc.	2010 Phase 1
10-1-A2.09-9697 GRC Inexpensive Reliable Oil-Debris Optical Sensor for Rotorcraft Health Monitoring, Translume, Inc.	2010 Phase 1
10-1-A2.03-9097 LaRC Implicit Higher Order Temporal Differencing for Aeroacoustic and CFD Applications, CFD Research Corporation	2010 Phase 1
10-1-A2.03-8991 LaRC Interior Acoustic Analysis for Early Use in Design, Michigan Engineering Services, LLC	2010 Phase 1

SBIR support for SRW

Title/ Performer	Year/Phase
10-1-A2.03-8233 LaRC Hybrid Element Method for Compsoite Structures Subjected to Boundary Layer Loading, Comet Technology Corporation	2010 Phase 1
A2.09-9045, "Towards More Efficient Comprehensive Rotor Noise Simulation," CASCADE Technologies Inc.	2009 Phase 1
A2.09-9343, "Enhanced Prediction of Gear Tooth Surface Fatigue Life," Sentient	2009 Phase 1
A2.09-8083, "Rotorcraft Diagnostics," Qualtech Systems, Inc	2009 Phase 1
A2.09-8823, "Flight Adaptive Blade For Optimum Rotor Response (FABFORR)," Continuum Dynamics, Inc.	2009 Phase 1
A2.09-8630, "Alumina Fiber-Reinforced 9310 Steel Metal Matrix Composite for Rotorcraft Drive System Components," Ultramet	2009 Phase 1
A2.09-9940, "Rotorcraft Diagnostics," Ridgetop Group, Inc.	2009 Phase 1
A2.09-9022, "Fast Responding PSP for Rotorcraft Aerodynamic Investigations," Innovative Scientific Solutions, Inc. (ISSI)	2008 Phase 2
A2.09-9167, "Hybrid Finite Element Analysis for Rotorcraft Interior Noise Simulations," Michigan Engineering Services, LLC	2008 Phase 2
A2.09-9022, Fast Responding PSP for Rotorcraft Aerodynamic Investigations, Innovative Scientific Solutions Inc	2008 Phase 2

SBIR support for SRW

Title/ Performer	Year/Phase
A2.09-8904, ROBUST (Rotorcraft Blade Universal Shape Transformation) System for Controlled Aerodynamic Warping, Materials Technologies Corporation	2008 Phase 1
A2.09-9167 Hybrid Finite Element Developments for Rotorcraft Interior Noise Computations within a Multidisciplinary Design Environment, Michigan Engineering Services, LLC	2008 Phase 1
A2.09-8605, Metal Rubber™ Sensor Appliqués for Rotor Blade Air, Nanosonic, Inc.	2008 Phase 1
A2.09-8759, A Surface-Mounted Rotor State Sensing System, Continuum Dynamics, Inc.	2008 Phase 1
A2.09-9451, Physics Based Tool for Rotorcraft Computational Aeroacoustics, Continuum Dynamics, Inc.	2008 Phase 1
Multifunctional Erosion Resistant Icephobic Appliques for Rotorblades, NanoSonic, Inc.	2007 Phase 2
Fully Integral, Flexible Composite Driveshaft, Lawrie Technology, Inc.	2007 Phase 2
Computational Wind Tunnel: A Design Tool for Rotorcraft, Sukra Helitek, Inc.	2007 Phase 2
Elastomeric Dampers derived from First-Principles-Based Analytical Simulation, Materials Technologies Corporation	2007 Phase 2

Publications

Publication	Authors/Presenter	Presented/Published
Rotorcraft Conceptual Design Environment	Wayne Johnson and Jeffrey D. Sinsay	2nd International Forum on Rotorcraft Multidisciplinary Technology, Seoul, Korea, October 19-20, 2009
Rotorcraft Conceptual Design Environment	Wayne Johnson and Jeffrey D. Sinsay	The 3rd International Basic Research Conference on Rotorcraft Technology, Nanjing, China, October 14-16, 2009
Computational Investigation of the Effects of Gurney Flap on the Forward Flight Characteristics of Helicopter Rotors	Min, B. Y., Sankar, L., Rajmohan, N., and JVR Prasad,	Journal of Aircraft, Vol. 46, No. 6, November – December 2009, pp. 1957 – 1964
Diffusion Bonding and Brazing Approaches for Silicon Carbide Based Systems'	Halbig, Singh, Coddington	Materials & Structures Technology 2009 Conference & Exposition held in Pittsburgh, PA on Oct. 26-29, 2009
The Use of 3-Dimensional Target Tracking Photogrammetric Techniques for Impact Testing of an MD-500 Helicopter and Lessons Learned	Justin D. Littell	AHS-HRC National Technical Specialists' Meeting for Rotorcraft Structures and Survivability, held on October 27-29, 2009, in Williamsburg, VA,
A Parametric Study on a Shell-Based Model of a Kevlar/Epoxy Composite Honeycomb	Michael A. Polanco	AHS-HRC National Technical Specialists' Meeting for Rotorcraft Structures and Survivability, held on October 27-29, 2009, in Williamsburg, VA,
A Parametric Study on a Solid-Based Model of a Kevlar/Epoxy Composite Honeycomb	Karen E. Jackson	AHS-HRC National Technical Specialists' Meeting for Rotorcraft Structures and Survivability, held on October 27-29, 2009, in Williamsburg, VA,
Development of a Finite Element Model of the MD-500 Helicopter for Full-Scale Testing	Martin Annett	AHS-HRC National Technical Specialists' Meeting for Rotorcraft Structures and Survivability, held on October 27-29, 2009, in Williamsburg, VA,
Modified adaptive control for region 3 operation in the presence of wind turbine structural modes	Frost, S. A., Balas, M. J., and Wright, A. D	48th AIAA Aerospace Sciences Meeting including the New Horizons Forum and Aerospace Exposition, 2010, AIAA 2010-249, 4-7 January 2010, Orlando, FL
Predicting the Dynamic Crushing Response of a Composite Honeycomb Energy Absorber using a Solid-Element-Based Model in LS-DYNA	Jackson, Karen E	11th LS-DYNA Users Conference, Dearborn, MI, June 6-8, 2010.
Use of LS-DYNA to Assess Impact Response of a Shell-Based Kevlar/Epoxy Composite Honeycomb	Michael Polanco	11th LS-DYNA Users Conference, Dearborn, MI, June 6-8, 2010.
LS-DYNA Analysis of a Full-Scale Helicopter Crash Test	Martin Annett	11th LS-DYNA Users Conference, Dearborn, MI, June 6-8, 2010.
Two-Speed Gearbox Dynamic Simulation Predictions and Test Validation	Lewicki, D.G., DeSmidt, H., Smith, E.C., and Bauman, S.W.	Presented at the 66th Annual Forum of the American Helicopter Society, Phoenix, May 10-12, 2010
Effects of gas turbine component performance on engine and rotary wing vehicle size and performance	C. A. Snyder and D. R. Thurman	Presented at the 66th Annual Forum of the American Helicopter Society, Phoenix, May 10-12, 2010
Assessment of aerodynamic challenges of a variable-speed power turbine for Large Civil Tilt-Rotor application	Welch, G. E. and Boyle, R. J.	Presented at the 66th Annual Forum of the American Helicopter Society, Phoenix, May 10-12, 2010

Publications

Publication	Authors/Presenter	Presented/Published
High Speed Gear Windage CFD Analysis and Application to the NASA Glenn Gear Windage Test Facility	Hill, M., Kunz, R, Noack, R., Long, L. and Handschuh, R.	Presented at the 66th Annual Forum of the American Helicopter Society, Phoenix, May 10-12, 2010
Compressor Conceptual Design for Two-Spool Core Engine for Large Civil Tilt Rotor Vehicle.	J. Veres	Presented at the 66th Annual Forum of the American Helicopter Society, Phoenix, May 10-12, 2010
Correlate Life Predictions and Condition Indicators in Helicopter Tail Gearbox Bearings	Dempsey, P., Branning, J., Keller, J., Wade D., and Bolander, N.	Presented at the 66th Annual Forum of the American Helicopter Society, Phoenix, May 10-12, 2010
“Receiver Operating Characteristic Analysis for Test Stand and Helicopter Oil Cooler Bearings	Dempsey, P.J., Bechhoefer, E., Branning, J., Keller, J., Wade D., and Lybeck, N.	Presented at the 66th Annual Forum of the American Helicopter Society, Phoenix, May 10-12, 2010
Use of FM4 Condition Indicator for Rotorcraft Gearbox Health Diagnoses	Branning, J., Antolick, L., Wade, D., and Dempsey, P.	Presented at the 66th Annual Forum of the American Helicopter Society, Phoenix, May 10-12, 2010
Full Scale Crash Test of a MD-500 Helicopter with Deployable Energy Absorbers	Kellas, S., Jackson, K. E., and Littell, J. D.,	Presented at the 66th Annual Forum of the American Helicopter Society, Phoenix, May 10-12, 2010
System-Integrated Finite Element Analysis of a Full-Scale Helicopter Crash Test with Deployable Energy Absorbers	Annett, M. S., and Polanco, M. A	Presented at the 66th Annual Forum of the American Helicopter Society, Phoenix, May 10-12, 2010
An Investigation of Large Tilt-Rotor Short-Term Attitude Response Handling Qualities Requirements in Hover	Carlos A. Malpica, William A. Decker, Colin R. Theodore, Chris L. Blanken, Tom Berger	Presented at the 66th Annual Forum of the American Helicopter Society, Phoenix, May 10-12, 2010
A Parameter Identification Method for Helicopter Noise Source Identification and Physics-Based Semi-Empirical Modeling	Greenwood, E., Schmitz, F.	Presented at the 66th Annual Forum of the American Helicopter Society, Phoenix, May 10-12, 2010
Direct CFD Predictions of Low Frequency Sounds Generated by Helicopter Main Rotors	Sim, B.W., Potsdam, M., Conner, D., Watts, M.	Presented at the 66th Annual Forum of the American Helicopter Society, Phoenix, May 10-12, 2010
Analysis of a Hovering Rotor in Icing Conditions	R. Narducci, E. Kreeger	Presented at the 66th Annual Forum of the American Helicopter Society, Phoenix, May 10-12, 2010
Investigation of Rotor Performance and Loads of a UH-60A with Individual Blade Control	H. Yeo, E. Romander, T. Norman	Presented at the 66th Annual Forum of the American Helicopter Society, Phoenix, May 10-12, 2010
A Computational Study of BVI Noise Reduction using Active Twist Control	D. Fogarty, M. Wilbur, M. Sekula	Presented at the 66th Annual Forum of the American Helicopter Society, Phoenix, May 10-12, 2010
Design and Performance Optimizations of Advanced Erosion-Resistant Low Conductivity Thermal Barrier Coatings for Rotorcraft Engines	Dongming Zhu, Robert A. Miller and Maria A. Kuczmarski	Presented at the 66th Annual Forum of the American Helicopter Society, Phoenix, May 10-12, 2010

Publications

Publication	Authors/Presenter	Presented/Published
High Speed Gear Windage CFD Analysis and Application to the NASA Glenn Gear Windage Test Facility	M. J. Hill, R. F. Kunz, R. W. Noack, L. N. Long, R. F. Handschuh,	Presented at the 66th Annual Forum of the American Helicopter Society, Phoenix, May 10-12, 2010
Validations of Coupled CSD/CFD and Particle Vortex Transport Method for Rotorcraft Applications: Hover, Transition, and High Speed Flights	Anusonti-Inthra, P.	Presented at the 66th Annual Forum of the American Helicopter Society, Phoenix, May 10-12, 2010
Extension-Twist Coupled Graphite/Epoxy Composite Driveshafts for Gear-Mesh Vibration Suppression	DeSmidt, H, and Zhao, J.,	Presented at the 66th Annual Forum of the American Helicopter Society, Phoenix, May 10-12, 2010
Investigation of Rotor Performance and Loads of a UH-60A with Individual Blade Control	Hyeonsoo Yeo, Ethan Romander, and Tom Norman	Presented at the 66th Annual Forum of the American Helicopter Society, Phoenix, May 10-12, 2010
High Speed GearWindage CFD Analysis and Application to the NASA Glenn Gear Windage Test Facility	Kunz and Handschuh	Presented at the 66th Annual Forum of the American Helicopter Society, Phoenix, May 10-12, 2010
Determining Effects of Time-Varying Rotorcraft Dynamics on Pilot Control	Nicoll, T.K., and Mitchell, D.G	Presented at the 66th Annual Forum of the American Helicopter Society, Phoenix, May 10-12, 2010
Use of Wavelet Scalograms to Characterize Rotorcraft Pilot-Vehicle System Interactions	Klyde, D.H., Schulze, P.C., Liang, C.Y., and Thompson, P.M	Presented at the 66th Annual Forum of the American Helicopter Society, Phoenix, May 10-12, 2010
Development and Evaluation of Reduced Order Models of On-Blade Control for Integrated Flight and Rotor Control	Olcer, F.E., Prasad, J.V.R., Sankar, L.N., Bain, J., Zhao, J., He, C.	Presented at the 66th Annual Forum of the American Helicopter Society, Phoenix, May 10-12, 2010
Low-Speed and High-Speed Correlation of SMART Active Flap Rotor Loads	S. Kottapalli	AHS Aeromechanics Specialists' Conference, January 20-22, 2010, Holiday Inn Fisherman's Wharf.
A Study of Acoustic Reflections in Full Scale Rotor Low Frequency Noise Measurements Acquired in Wind Tunnels	Barbely, Sim, Kitaplioglu, Goulding	AHS Aeromechanics Specialists' Conference, January 20-22, 2010, Holiday Inn Fisherman's Wharf.
Integration of Rotor Aerodynamic Optimization with the Conceptual Design of a Large Civli Tiltrotor	C. W. Acree	AHS Aeromechanics Specialists' Conference, January 20-22, 2010, Holiday Inn Fisherman's Wharf.
Analytical, First Principles Modeling of Elastomeric Dampers	S. Kottapalli, O. Bauchau, C. Ju, S. Ozbay, Y. Mehrotra	AHS Aeromechanics Specialists' Conference, January 20-22, 2010, Holiday Inn Fisherman's Wharf.
Icing Studies fo the UH-60A Rotor in Forward Flight	N. Rajmohan, J. Bain, M. Nucci, L. Sankar, R. Flemming, T. Egolf, R. Kreeger	AHS Aeromechanics Specialists' Conference, January 20-22, 2010, Holiday Inn Fisherman's Wharf.
Airloads Predication of a UH-60A Rotor Inside the 40-by 80-Foot Wind Tunnel	I. Chang, E. Romander, M. Potsdam, H. Yeo	AHS Aeromechanics Specialists' Conference, January 20-22, 2010, Holiday Inn Fisherman's Wharf.

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Large-Scale Domain Decomposition for a Scalable, Three-Dimensional Brinck Finite Element Based Rotor Dynamic Analysis	A. Datta, W. Johnson	AHS Aeromechanics Specialists' Conference, January 20-22, 2010, Holiday Inn Fisherman's Wharf.
Development and Operation of an Automatic Rotor Trim Control System for the UH-60 Individual Blade Control Wind Tunnel Test	C. Theodore, M. Tischler	AHS Aeromechanics Specialists' Conference, January 20-22, 2010, Holiday Inn Fisherman's Wharf.
Optimization of Overset Solution Adaptive Grids for Hovering Rotorcraft	T. Holst, T. Pulliam	AHS Aeromechanics Specialists' Conference, January 20-22, 2010, Holiday Inn Fisherman's Wharf.
Retrofeflective Backgoudn Oriented Schlieren (RBOS) as applied to Full-scale UH-60 Blade Tip Vortices	J. Heineck, L. Kushner, E. Schairer, L. Walker	AHS Aeromechanics Specialists' Conference, January 20-22, 2010, Holiday Inn Fisherman's Wharf.
Non-Intrusive Measurements of a Four-Bladed Rotor in Hover--A First Look	O. Wong, K. Noonan, A. Watkins, L. Jenkins, C-S Yao	AHS Aeromechanics Specialists' Conference, January 20-22, 2010, Holiday Inn Fisherman's Wharf.
Blade Deflection Measurements of a Full-Scale UH-60A Rotor System	L. Olson, A. Abrego, D. Barrows, A. Burner	AHS Aeromechanics Specialists' Conference, January 20-22, 2010, Holiday Inn Fisherman's Wharf.
NDARC--NASA Design and Analysis of Rotorcraft: Theoretical Basis and Architecture	W. Johnson	AHS Aeromechanics Specialists' Conference, January 20-22, 2010, Holiday Inn Fisherman's Wharf.
NDARC--NASA Design and Analysis of Rotorcraft: Validation and Demonstration	W. Johnson	AHS Aeromechanics Specialists' Conference, January 20-22, 2010, Holiday Inn Fisherman's Wharf.
Design of a Slowed-Rotor Compound Helicopter for Future Joint Service Missions	C. Silva, H. Yeo, W. Johnson	AHS Aeromechanics Specialists' Conference, January 20-22, 2010, Holiday Inn Fisherman's Wharf.
Converting a C-130 Hercules into a Compound Helicopter: A Conceptual Design Study	A. Kottapalli, F. Harris	AHS Aeromechanics Specialists' Conference, January 20-22, 2010, Holiday Inn Fisherman's Wharf.
A Framework for Robust Rotorcraft Flight Control Design	R. Hess, University of CA	AHS Aeromechanics Specialists' Conference, January 20-22, 2010, Holiday Inn Fisherman's Wharf. (Also submitted to Journal of the American Helicopter Society)
Modeling Biodynamic Interference in Helicopter Piloting Tasks	R. Hess, University of CA	AHS Aeromechanics Specialists' Conference, January 20-22, 2010, Holiday Inn Fisherman's Wharf.
NDARC, NASA Design and Analysis of Rotorcraft	W. Johnson	NASA TP 2009-215402, December 2009
Impact of Aerodynamics and Structures Technology on Heavy Lift Tiltrotors	W. Acree	Journal of the American Helicopter Society, Vol. 55, No 1

Publications

Publication	Authors/Presenter	Presented/Published
Active Metal Brazing and Characterization of Brazed Joints Between Silicon Carbide and Metallic Systems	Bryan Coddington, Mike Halbig	34th International Conference and Exposition on Advanced Ceramics and Composites, January 24-29, 2010, Daytona Beach, FL
Rotorcraft Aerodynamics and Icing	Sarofeen, C., Kinzel, M., Noack, R	Mid-Atlantic OpenFOAM Users Group Meeting, March 27th, 2010
Development and Application of Agglomerated Multigrid Methods for Complex Geometries	Diskin, B., Nishikawa,	AIAA Conference, Chicago, 2010
Textbook-efficiency multigrid solver for three-dimensional unsteady compressible Navier–Stokes equations	Liao, W., Diskin, B., Peng, Y., Lou, L.-S	Journal of Computational Physics, 227 (2008) 7160–7177
Acoustic Calibration of the Exterior Effects Room at the NASA Langley Research Center	Faller II, K.J., Rizzi, S.A., Klos, J., Chapin, W.L., Surucu, F., Aumann, A.R.	159th Meeting of the Acoustical Society of America and Noise-Con 2010, Baltimore, MD, April 19-23, 2010.
Augmented Adaptive Control of a Wind Turbine in the Presence of Structural Modes	Frost, S. A., Balas, M. J., Wright, A. D	American Control Conference (ACC), 2010, pp.2760-2765, 30 June – 2 July 2010, Baltimore, MD
A New Analysis Tool Assessment for Rotordynamic Modeling of Gas Foil Bearings	Dr. Samuel Howard, and r Luis SanAndrés, Texas A&M University	Journal of the American Society of Mechanical Engineers (ASME)
Deployable System for Crash-Load Attenuation	Kellas, S. and Jackson, K	Journal of the American Helicopter Society
Multi-Terrain Vertical Drop Tests of a Composite Fuselage Section	Kellas, S. and Jackson, K	Journal of the American Helicopter Society
Vertical Drop Testing and Analysis of the WASP Helicopter Skid Gear	Fuchs, Y. T., and Jackson, K. E	Journal of the American Helicopter Society
A Computational Approach for Model Update of an LS-DYNA Energy Absorbing Cell	Horta, L. G., Jackson, K. E., and Kellas, S	Journal of the American Helicopter Society
Large Field Photogrammetry Techniques for Aircraft and Spacecraft Impact Testing	Justin Littell	Society for Experimental Mechanics (SEM), Indianapolis
Assessment of predictive capability of aeromechanics methods	William Bousman and Thomas Norman	Journal of the American Helicopter Society, Vol 55, No 1, 012001
Impact of Aerodynamics and Structures Technology on Heavy Lift Tiltrotors	C. W. Acree, Jr.	Journal of the American Helicopter Society, Vol 55, No 1, 012002

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In-flight Array Measurements of Tail Rotor Harmonic Noise	D. C. Sargent, F. H. Schmitz, B. W. Sim	Journal of the American Helicopter Society, Vol 55, No 1, 012006
Selection of Rotor Solidity for Heavy Lift Tiltrotor Design	Hyeonsoo Yeo, Jeffrey Sinsay, C. W. Acree, Jr.	Journal of the American Helicopter Society, Vol 55, No 1, 012010
An OpenFOAM Implementation of Ice Accretion for Rotorcraft	Kinzel, M., Noack, R., Sarofeen, C., Boger, D.A., Miller, S.	the 5th OpenFOAM Workshop, Chalmers, Gothenburg, Sweden, June 21-24, 2010.
A Numerical Investigation of Droplet/Particle Impingement on Dynamic Airfoils and Rotor Blades	Sarofeen, C., Kinzel, M., Noack, R., Morris, P., Kreeger, R	AIAA Paper 2010-4229, Presented at the 28th AIAA Applied Aerodynamics Conference, , Chicago, IL, Jun 28th-July1st, 2010.
A Finite-Volume Approach to Modeling Ice Accretion	Kinzel, M., Noack, R., Sarofeen, C., Morris, P., and Kreeger, R	AIAA Paper 2010-4230, Presented at the 28th AIAA Applied Aerodynamics Conference, Chicago, IL, Jun 28th-July1st, 2010
A Methodology for Modeling Effects of Icing on Rotary Wing Aerodynamics	Nucci, M., Bain, J., Sankar, L., Egolf, T.A., Flemming, R., and Kreeger, E.,	36th European Rotorcraft Forum, Paris, France, 7-9 September, 2010
Validation of a Polyimide Foam Model for Use in Transmission Loss Applications	Hong, K., Bolton, J., Cano, R., Weiser, E., Jensen, B., Silcox, R., Howerton, B., Maxon, J., Wang, T., and Lorenzi, T	NOISE-CON 2010 Conference in Baltimore, Maryland on April 19-21, 2010
Microstructural and Mechanical Evaluation of a Cu-Based Active Braze Alloy to Join Silicon Nitride Ceramics	Dr. Mrityunjay Singh	Journal of European Ceramic Society
Evaluation of an Externally Deployable Energy Absorber for Crash Applications	Jackson, K. E., Kellas, S., Annett, M. S., Littell, J., and Polanco, M. A.,	International Crashworthiness Conference, Leesburg, VA, September 22-24, 2010
Crash Test of an MD-500 Helicopter with a Deployable Energy Absorber Concept	Littell, J. D., Jackson, K. E., and Kellas, S.,	International Crashworthiness Conference, Leesburg, VA, September 22-24, 2010.
Modeling and Characterization of Macro-Fiber Composite Transducers for Lamb Wave Excitation	M. Collet, M. Ruzzene, K. Cunefare, B. Xu	Proceedings of the Non-Destructive Evaluation/Smart Materials and Structures Conference, San Diego CA, March 2010.
Periodic Piezoelectric Sensor-Actuator Array for Vibration Suppression on a Beam	B. Beck, K. Cunefare, M. Ruzzene, M. Collet,	Proceedings of the Smart Materials and Structures Conference, San Diego CA, March 2010.
Acoustic calibration of the Exterior Effects Room at the NASA Langley Research Center	Faller II, K.J., Rizzi, S.A., Klos, J., Chapin, W.L., Surucu, F., and Aumann, A.R.	159th Meeting of the Acoustical Society of America and Noise-Con 2010, Baltimore, MD, on April 22

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Publication	Authors/Presenter	Presented/Published
Automatic Tip Vortex Core Profiling for Numerical Flow Simulations of Rotorcraft	Kao, D. and Chaderjian, N.,	AIAA Paper No. 2010-4752, June 2010, to be presented at the 40th AIAA Fluid Dynamics Conference in Chicago, Ill from June 28th to July 1, 2010
Assessment of the Effects of Computational Parameters on Physics-Based Models of Ice Accretion	Nucci, M., Bain, J., Sankar, L., Kreeger, R.E., Egolf T.A., Flemming, R.,	AIAA-2010-1277, presented at the 48th AIAA Aerospace Sciences Meeting, Orlando, FL, 4-7 January, 2010
A Methodology for Modeling the Effects of Icing on Rotary Wing Aerodynamics	Rajmohan, N., Nucci, M., Sankar, L. N., Flemming, R., Egolf, T. A., and Kreeger, R. E.	2010 European Rotorcraft Forum, September 2010
Sizing Single Cantilever Beam Specimens for Characterizing Facesheet/Core Peel Debonding in Sandwich Structure	James G. Ratcliffe	NASA TP-2010-216169, January 2010
Testing and Evaluation of Flexible Matrix Composite Tubes Subjected to Ballistic Impact Damage	S. G. Sollenberger, J. L. Bail2, L. Kohlman, C. E. Bakis, G. D. Roberts, E. C. Smith	ASC2010 conference (American Society for Composites) this Fall in Dayton, OH 2010
Advanced textile composite structures	Nageswara R. Janapala, Fu-Kuo Chang, Robert K. Goldberg, Gary D. Roberts and Karen E. Jackson	11th International LS-DYNA® Users Conference.
Acoustic calibration of the Exterior Effects Room at the NASA Langley Research Center	Faller II, K.J., Rizzi, S.A., Klos, J., Chapin, W.L., Surucu, F., and Aumann, A.R.,	159th Meeting of the Acoustical Society of America and Noise-Con 2010, Baltimore, MD, on April 22.
Improved Generator Speed Regulation in the Presence of Structural Modes through Adaptive Control with Residual Mode Filter"	Susan Frost	Submitted to Mechatronics, The Science of Intelligent Machines, A Journal of IFAC, the International Federation of Automatic Control, Special Issue on Wind Energy.
Analysis of a Dual Gearbox/Shaft System with Nonlinear Dynamic Mesh Phase Interactions	H. DeSmidt	51st AIAA Structures, Dynamics, and Materials Conference, April 12-15, 2010, Orlando, FL
Offset Compound Gear	Mark A. Stevens, Dr. Robert F. Handschuh, Dr. David G. Lewicki	May 2010 issue of NASA Tech Briefs Magazine (Vol. 34, No. 5, pp. 49-50)
Determining the effects of low frequency noise on humans	Yuriy Gurovich, Geoff Leventhal Daniel Robinson, Ben Sharp	14th International Meeting on Low Frequency Noise and Vibration and its Control Aalborg, Denmark 9 – 11 June 2010

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Publication	Authors/Presenter	Presented/Published
Offset Compound Gear	Mark A. Stevens,/Dr. Robert F. Handschuh, and Dr. David G. Lewicki	Tech Brief article for LEW-18370-1, published May 2010 issue of NASA Tech Briefs (Vol 34, No 5, pp 49-50)
Acoustic calibration of the Exterior Effects Room at the NASA Langley Research Center	Faller II, K.J., Rizzi, S.A., Klos, J., Chapin, W.L., Surucu, F., and Aumann, A.R.,	159th Meeting of the Acoustical Society of America and Noise-Con 2010, Baltimore, MD, April 22, 2010
Assessment of an Externally Deployable Energy Absorbing Concept for Improved Helicopter Crash Protection	Karen E. Jackson	Aircraft Survivability Symposium 2010, held at the Naval Postgraduate School in Monterey, CA on November 2-5, 2010
A Computational Approach for Model Update of an LS-DYNA Energy Absorbing Cell	Horta, L. G., Jackson, K. E., and Kellas, S.,	Journal of the American Helicopter Society, Vol. 55, No. 3, July 2010, pp. 032011-1 through 032011-8
Assessment of Soil Modeling Capability for Orion Contingency Land Landing	Ernie Heymsfiel and Ed Fasanella	ASCE Journal of Aerospace Engineering
Technology Assessment for Large Vertical-Lift Transport Tiltrotors	Germanowski, Stille, Strauss	NASA CR-2010-216384
Remaining Technical Challenges and Future Plans for Oil-Free Turbomachinery	DellaCorte, C. and Bruckner, R.	Journal of Engineering for Gas Turbines and Power
A New Analysis Tool Assessment for Rotordynamic Modeling of Gas Foil Bearings	Howard, S.A.	Journal of Engineering for Gas Turbines and Power
A Three-Dimensional Foil Bearing Performance Map Applied to Oil-Free Turbomachinery	Radil, K, DellaCorte, C.	publication in Tribology Transactions
Remaining Technical Challenges and Future Plans for Oil-Free Turbomachinery	DellaCorte, C., Bruckner, R.	International Gas Turbine Institute Turbo Expo 2010 Conference
A New Analysis Tool Assessment for Rotordynamic Modeling of Gas Foil Bearings	Howard, S.A.	International Gas Turbine Institute Turbo Expo 2010 Conference, Paper number GTP-10-1082).
A Novel Thermal Management Approach for Radial Foil Air Bearings	Radil, K.	STLE 65th Annual Meeting
The Effect of Composition on the Surface Finish of PS400: A New High Temperature Solid Lubricant Coating	DellaCorte, C, Stanford, M.K., Thomas, F., Edmonds,B.J.	STLE 65th Annual Meeting
Automatic Tip Vortex Core Profiling for Numerical Flow Simulations of Rotorcraft in Hover	Kao & Chaderjian	40th AIAA Fluid Dynamics conference, Chicago, IL

Publications

Publication	Authors/Presenter	Presented/Published
The development of a Large Civil Tiltrotor Simulation for Hover and Low-speed Handling Qualities Investigations	Ben Lawrence	2010 European Rotorcraft Forum, Paris
A New Solution Adaption Capability for the OVERFLOW CFD Code	Pieter Buning	10th Symposium on Overset Composite Grid & Solution Technology, Sept. 20-23, 2010, NASA Ames Research Center, CA
Progress in Time Accurate CFD-CSD Based Aeroelasticity of Helicopter blades	Guru Guruswamy	NRTC Airloads Workshop, Arlington, Aug 20, 2010
Rotorcraft Transmission Noise Path Model, Including Distributed Fluid Film Bearing Impedance Modeling	Hambric, Stephen, A.; Hanford, Amanda, D.; Shepherd, Micah, R.; Campbell, Robert, L.; Smith, Edward, C	NASA/CR-2010-216812
Boeing-SMART Rotor Wind Tunnel Test Data Report for DARPA Helicopter Quieting Program (HQP), Phase 1B.	Lau, B. H., Obriecht, N., Gasow, T., Hagerty, B., Cheng, C., and Sim, B. W.	NASA/TM-2010-216404, September 2010
Automatic Tip Vortex Core Profiling for Numerical Flow Simulations of Rotorcraft in Hover	D. Kao and N. Chaderjian	AIAA 40th Fluid Dynamics Conference, AIAA 2010-4752
A New Solution Adaption Capability for the OVERFLOW CFD Code	Pieter Buning	Overset Composite Grid and Solution Technology, Sept 20-23, 2010, NASA Ames Research Center
Progress Towards Fuselage Drag Reduction via Active Flow Control: A Combined CFD and Experimental Effort	Schaeffler, Allan, et al	Presented paper at European Rotorcraft Forum (ERF), Sept. 2010.
Multi-Terrain Vertical Drop Tests of a Composite Fuselage Section	Kellas S. and Jackson K. E.,	Journal of the American Helicopter Society, Vol. 55, No. 4, October 2010, pp. 042002-1 through 042002-7
Deployable System for Crash-Load Attenuation	Kellas S. and Jackson K. E.,	*Journal of the American Helicopter Society*, Vol. 55, No. 4, October 2010, pp. 042001-1 through 042001-14.
Augmented adaptive control of flexible structures using residual mode filters	Balas, M. J. and Frost, S. A	ASME 2010 Conference on Smart Materials, Adaptive Structures and Intelligent Systems, 2010, SMASIS2010-3624, 28 September – 1 October 2010, Philadelphia, PA
Acoustic performance of an installed real-time three-dimensional audio system	Steve Rizzi	160th Meeting of the Acoustical Society of America, November 15-19, 2010
Assessment of an Externally Deployable Energy Absorbing Concept for Improved Helicopter Crash Protection	Karen Jackson	Aircraft Survivability Symposium 2010, Naval Postgraduate School in Monterey, California on November 2-5, 2010

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A Comparative Evaluation of Two Helicopter Crash Tests	Karen Jackson, Sotiris Kellas, Martin Annett, Justin Littell, and Michael Polanco	Sixth Triennial International Aircraft Fire and Cabin Safety Research Conference, held in Atlantic City, NJ, on October 25-28, 2010
Microstructural and Mechanical Evaluation of a Cu-based Active Braze Alloy to Join Silicon Nitride Ceramics	M. Singh, R. Asthana, F.M. Varela and J. Martínez-Fernández	Journal of European Ceramic Society
Active Metal Brazing of Silicon Nitride to Metals using Refractory Metal Interlayers	R. Asthana, M. Singh, and J. Martínez-Fernández	3rd International Congress on Ceramics (ICC-3), Osaka, Japan, November 2010
Summary of the Large Civil TiltRotor (LCTR2) Engine Gearbox Study	Chris Snyder, Mark Robuck and Joseph Wilkerson, and Carl Nordstrom	AHS International Powered Lift Conference, Oct. 5-7, 2010 (Philadelphia, PA.)
A New Analysis Tool Assessment for Rotordynamic Modeling of Gas Foil Bearings	Howard, S.A.	ASME Journal of Engineering for Gas Turbines and Power
Rotorcraft and Enabling Robotic Rescue	L. Young	HeliJapan 2010 conference, Nov. 1-3, 2010 in Omiya, Japan
Milestones in Aeromechanics	Wayne Johnson	HeliJapan 2010 conference, Nov. 1-3, 2010 in Omiya, Japan
Overview of the Subsonic Rotary Wing Project	Isaac Lopez	HeliJapan 2010 conference, Nov. 1-3, 2010 in Omiya, Japan
Overview of the Novel Intelligent JAXA Active Rotor Program	S. Saito, N. Kobiki, Y. Tanabe, W. Johnson, G. Yamauchi, and L. Young	HeliJapan 2010 conference, Nov. 1-3, 2010 in Omiya, Japan
Measuring Time-Varying Human Pilot Behavior	Ron Hess	AIAA 2011 Atmospheric Flight Mechanics Conference
A Framework for Robust Rotorcraft Flight Control Design	Ron Hess	Journal of the American Helicopter Society
Adaptive control of flexible structures using residual mode filters	Balas, M. J. and Frost, S. A.,	49th IEEE Conference on Decision and Control, 2010, 15-17 December 2010, Atlanta, GA
Adaptive control of non-minimum phase modal systems using residual mode filters: Part I & Part II	Balas, M. J. and Frost, S. A	Council of European Aerospace Societies 1st European Aerospace Guidance, Navigation and Control Conference, 13-15 April 2011, Munich, Germany.

Publications

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Improved generator speed regulation in the presence of structural modes through adaptive control using residual mode filters	Frost, S. A., Balas, M. J., and Wright, A. D.,	Mechatronics Special Issue: Past, present and future modeling and control of wind turbines, Elsevier Science Ltd,
Adaptive control using residual mode filters applied to wind turbines	Frost, S. A. and Balas, M. J.,	AIAA Infotech@Aerospace Conference 2011, 29-31 March 2011, St. Louis, MO
Ballistic Impact Tolerance of Filament-Wound Composite Tubes with Rigid and Flexible Matrix Materials	Sollenberger, Bail, Kohlman, Ruggeri, Bakis, Roberts, Smith	Proc. 25th Tech. Conf., American Society for Composites, DEStech Publications, Lancaseter, PA paper no. 1183.
High Speed Gear Windage Research	R. Handschuh	International Conference on Gearing, Munich Germany Oct 4-6, 2010
Real-time Acoustic Performance of the EER	John Faller	2nd Pan-American/Iberian Meeting on Acoustics, in Cancun, Mexico, on November 15-19, 2010
High Speed Gear Windage CFD Analysis and Application to the NASA Glenn Gear Windage Test Facility	M. J. Hill, R. F. Kunz, R. W. Noack, L. N. Long,, R. F. Handschuh	ASME Journal of Fluids Engineering, accepted
Multi-Dimensional Correlation of Impact Dynamic Models	Horta, L. G., Reaves, M. C., Annett, M. S., and Jackson, K. E.	2011 IMAC XXIX A Conference and Exposition on Structural Dynamics, Jacksonville, FL, Jan. 31 – Feb. 3, 2011
Seeding Cracks Using a Fatigue Tester for Accelerated Gear Tooth Breaking	Nenadic, N., Wodenscheck, J., Thurston, M., and Lewicki, D.,	2011 IMAC XXIX A Conference and Exposition on Structural Dynamics, Jacksonville, FL, Jan. 31 – Feb. 3, 2011
Grease Degradation in Critical Helicopter Drivetrain Bearings	Dykas, B., Krantz, T., Berger, G., Street, K., and Morales, W.,	Proceedings of the STLE/ASME International Joint Tribology Conference, 17-21 Oct. 2010, San Francisco, CA. #IJTC2010-41200.
Feasibility of an Unattached Ducted Burner Rig for Evaluating the Erosion Resistance of Thermal Barrier Coatings	Robert A. Miller, Maria A. Kuczmarski and Dongming Zhu	NASA TM
CFD-Guided Development of Rigs for Studying Erosion and Large Particle Damage of Thermal Barrier Coatings,	Maria A. Kuczmarski, Robert A. Miller, Dongming Zhu	Special Issue on "Advances in Computational Fluid Dynamics and Its Applications" for the Journal -- Modelling and Simulation in Engineering
Active damping using distributed anisotropic actuators	Noah Schiller, Ran Cabell, Juan Quinones, and Nathan Wier	2010 ASME International Mechanical Engineering in Vancouver, BC
High Speed Gear Windage CFD Analysis and Application to the NASA Glenn Gear Windage Test Facility	Hill, M., Kunz, R, Noack, R., Long, L. and Handschuh, R.	ASME Journal of Fluids Engineering

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Gear Fault Detection Effectiveness As Applied To Tooth Surface Pitting Fatigue Damage	David G. Lewicki, Paula J. Dempsey, Gregory F. Heath and Perumal Shanthakumaran	November/December 2010 issue of Gear Technology
CFD-Guided Development of Rigs for Studying Erosion and Large Particle Damage of Thermal Barrier Coatings	Maria A. Kuczmarski, Robert A. Miller, Dongming Zhu	Advances in Computational Fluid Dynamics and Its Applications, Journal Modelling and Simulation in Engineering
Feasibility of an Unattached Ducted Burner Rig for Evaluating the Erosion Resistance of Thermal Barrier Coatings	Robert A. Miller, Maria A. Kuczmarski and Dongming Zhu	NASA TM
Vertical Drop Testing and Analysis of the WASP Helicopter Skid Gear	Fuchs, Y. T., and Jackson, K. E.	Journal of the American Helicopter Society, Vol. 56, No. 1, January 2011, pp. 012005-1 through 012005-10
Effects of Icing on Rotary Wing Loads and Surface Heat Transfer Rates	Eric Kreeger	49th AIAA Aerosciences Meeting, Orlando, Jan, 2011